GRWOTH PERFORMANCE OF CERTAIN PULSE CROPS IN RESPONSE TO COAL SMOKE POLLUTION

ABSTRACT

Ph. D. THESIS

IN

BOTANY

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DEPARTMENT OF BOTANY
ALIGARH MUSLIM UNIVERSITY
ALIGARH (INDIA)

1995

ABSTRACT

The problem of air pollution of India although localized in certian pockets is becoming serious. The coal firing thermal power plants are chief source of air pollution, specially of SO_2, NO_X, Co_2, CO and other particulate pollutants SO_2, one of the potent phytotoxic pollutant causes severe damage to vegetation. Earlier Studies on SO_2 pollution were based on appearence of visible injury symptoms. But the recent studies have brought to light that SO_2 pollution might also affect the plant growth and yield without any visible injury involving the normal physiology and biochemical process in plants. Further much of the information available at hand is based on the studies carried out under artificial fumigation and not on plant growing under natural field condition.

The present work has been carried out to study the impact of coal smoke pollution on growth, yield and biochemical responses of some important pulse crops namely *C. arietinum*, *L. culinaris* and *P. sativum*.

All the parameters of the selected crops have been studeied for period of 100 days at an interval of 20 days.

Shoot and Root length :

Shoot length enhanced at seedling stage upto 40 days in call crops, except *C.arietinum* in which shoot growth was marginal increased up to 20 days. The root length suffered a heavy loss at all stages of growth except first stage in

which loss was only marginal under coal smoke pollution.

Growth index

It was more than one up to 40 days and less than one after in shoot growth but in case of Root growth, the growth index was invariably lesser than one in all stages in all the three crops.

Number of branches per Plant

The number of branches showed highly significant loss from 60 days to the harvest stage in all the three crops under coal smoke pollution.

Number of leaves per plant

The number of leaves per plant was affected from preflowering to final stage. In case of *P. sativum* and *L. culinaris* the loss was significant even at the seedling stage.

Number of leaflet per leaf

Leaflet number per leaf decreased at all stages of growth in all the species.

Leaflet area

The coal-smoke pollution promoted leaflet size to a significant level from seedling to harvest stage in all the three crops as compared to control except *C.arietinum*, which showed a marginal reduction in leaflet area at seedling stag

Leaf areas

The average area per leaf was affected in all the three crops. In *P.sativum*, there was a consistent increase in individual leaf area while in the other two species it was just opposite.

The total green area

The total green area per plant suffered heavy loss under coal smoke pollution.

Shoot and root biomass

All the three crops faced significant loss at all stages of growth except the seedling stage in which there was a marginal gain of shoot biomass. Root biomass suffered heavy loss at all stages of growth including the seedling stage.

Phytomass

The phytomass showed the same result as the shoot biomass at all stages of growth except the seedling stage

Net primary productivity (N.P.P.)

N.P.P. of plant was also hampered under coal smo pollution. The loss was maximum in *P. sativum* (46%), moderate in *C.arietinum* (44%) and low in *L. culinaris* (28%).

Yield

The maximum loss in yield was noted in *C.arietinum* (34%), and it was 32 % in *P.sativum* and 24 % in *L.culinaris*. The harvest index has revealed heavy loss in *P.sativum* (28%). The flowering as well as fruit setting was affected in all the three crops due to coal smoke pollution.

Reproductive growth activity

Number of flower per plant, number of fruit per plant, number of seed per pod, number of seed per plant and hundred seed weight were significantly affected in all the three crops under coal smoke pollution. The severity of loss in the harvest index was noted as *P. sativum* > *C. arietinum* > *L. culinaris*. Data obtained on seed viability, seed germination and reproductive capacity reveals that all the three crops suffered heavy loss, *P. sativum* facing the worst.

Biochemical analysis

The loss in Chlorophyll "a" was highly significant at all stages of growth under coal smoke pollution. While Chlorophyll "b" and carotenoids continue to decrease from flowering to the final stage in all the three crops. Unlike the chlorophylls, the carotenoids continue to form till the last stage in control as well as in the polluted population in all the three crops. Chlorophyll "a" is more sensitive to coal smoke pollution than chlorophyll "b". Chlorophyll showed higher vulnerability than carotenoids to coal smoke pollution.

Protein

The average protein content in roots and shoots in general, decreased in the polluted population with the roots having higher loss than the shoots.

Sulphate-sulphur

The increase sulphate-sulphur content in shoots was highly significant at all stages of growth, in all excepting *C.arietium* which showed a moderate increase at the seeding stage. While in roots it was only marginal up to 40 days, and later it became high under coal smoke pollution.

The nitrogen, phosphorus and protien content of seeds decreased significantly under the pollution stress in all the three species.

Nitrogen

Under the polluted atmosphere the loss in nitrogen became high with the increasing age of the plant in all the three crops, with *L.culinaris* having the haviest loss.

Phosphorus

Severe depletion of phosphorus was recorded under coal smoke pollution from flowering stage in *C.arietinum* and *L.culinaris* while in *P. sativum* the same occurred from preflowering stage.

Potassium

The potassium level decreased in all the three crops at different stages of growth under coal smoke pollution.

The statistical analysis of the data has revealed that the different parameters in a species differ in degree of sensitivity. Depanding on the age of the plant.

According to the degree of response of different parameters, the selected species are listed below in the decreasing order of sensitivity.

1. **Shoot length**

   C. arietinum = *L. culinaris* > *P. sativum*

2. **Root length**

   L. culinaris = *P. sativum* = *C. arietinum*

3. **Branch number per plant**

   P. sativum > *C. arietinum* > *L. culinaris*

4. **Leaf number per plant**

   P. sativum > *C. arietinum* > *L. culinaris*

5. **Leaflet number per leaf**

   P. sativum > *L.culinaris* > *C. arietinum*

6. **Area per leaflet**

   P. sativum > *C. arietinum* > *L. culinaris*

7. **Area per leaf**

   L. culinaris > *C. arietinum* > *P. sativum*

8. **Total green area per plant**

   P. sativum > *C. arietinum* > *L. culinaris*

9. **Shoot biomass**

   L. culinaris > *P. sativum* > *C. arietinum*

10. **Root biomass**

    L. culinaris > *C. arietinum* *P. sativum*

11. **Phytomass**

    P. sativum *C. arietinum* > *L. culinaris*

12. **Net primary productivity**

    P. sativum > *C. arietinum* > *L. culinaris*

13. **Flower number per plant**

    L. culinaris > *C. arietinum* > *P. sativum*

14. **Fruit number per plant**

    C. arietinum > *P. sativum* > *L. culinaris*

15. **Seed number per pod**

P. sativum > C. arietinum > L. culinaris

16. **Seed number per plant**

C. arietinum > P. sativum > L. culinaris

17. **Seed weight**

L.culinaris > P. sativum > C. arietinum

18. **Harvest index**

P. sativum > C. arietinum > L. culinaris

19. **Seed viability**

P. sativum > C. arietinum = L. culinaris

20. **Seed germination**

P. sativum > C. arietinum > L. culinaris

21. **Reproductive capacity**

P. sativum > C. arietinum > L. culinaris

22. **Chlorophyll 'a'**

C. arietinum > P. sativum > L. culinaris

Chlorophyll 'b'

P. sativum > C. arietinum > L. culinaris

Total chlorophyll

C. arietinum > P. sativum > L. culinaris

Carotenoids

P. sativum > C. arietinum = L. culinaris

23. **Protein content in root**

C. arietinum > P. sativum > L. culinaris

Protein content in shoot

L.culinaris > P. sativum > C. arietinum

Average protein content of root and shoot

P. sativum > C. arietinum > L. culinaris

24. **Sulphate-sulphur content in root**

P. sativum > *C. arietinum* > *L. culinaris*

Sulphate-sulphur content in shoot

P. sativum > *C. arietinum* > *L. culinaris*

Average sulphate-sulphur content of root and shoot

P. sativum > *C. arietinum* > *L. culinaris*

25. **Nitrogen content**

P. sativum = *C. arietinum* > *L. culinaris*

26. **Phosphorus content**

C. arietinum > *P. sativum* > *L. culinaris*

27. **Potassium content**

C. arietinum > *L. culinaris* > *P. sativum*

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DEDICATED
TO MY
HUSBAND

ALIGARH MUSLIM UNIVERSITY
DEPARTMENT OF BOTANY, ALIGARH -202 002, INDIA Tel. (0571) 25676

A. K. M. GHOUSE
M.Sc., Ph.D., F.L.S., F.A.E.B
Professor

Dated

CERTIFICATE

This is to certify that the thesis entitled **"Growth Performance of Certain Pulse Crops in response to coal smoke pollution"** embodies original and bonafide work carried out under my supervision by **Ms. Azra Perveen**. It may be submitted to the Aligarh Muslim University, Aligarh towards the fulfilment of requirements for the degree of **Doctor of Philosphy in Botany.**

(A.K.M. Ghouse)

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Azra Perveen

(AZRA PERVEEN)

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INTRODUCTION

INTRODUCTION

The health and welfare of mankind is ultimately linked with the viability and productivity of natural and agricultural ecosystems. Evidences accumulated over the past several decades have clearly demonstrated that both yield and integrity of these life supporting ecosystem can be adversely affected by pollution. While considering the air quality, the objectives are set out to understand the effects of substances in the atmosphere on plants, whether they are beneficial or adverse.

Air pollution is the by-product of man's quest and activities for more comfort. The process involving chemicals, metal manufacturings, electric power generation and increasing transportation load in heavily populated cities caused the problem of air pollution to become inevitable. During the past many decades, there has been a growing awareness of the serious hazards of atmospheric pollution affecting the normal growth, development and survival of plants.

The problem of air pollution in India, although localized in certain pockets, is becoming serious. India has vast reserves of coal and, therefore, a considerable amount of electric power is produced through coal-firing thermal power plants. One of them is the Hardua Ganj Thermal Power Plant (HTPP) situated 16 kms. North East of the Aligarh City. The HTPP, which came up here some 50 years back, is the chief source of atmospheric pollution in and around Aligarh. The chief pollutants emanating out of coal burning from the thermal power plants are SO_2, NO_x, CO_2, CO and other particulate pollutants.

SO_2, the chief phytotoxic pollutant in coal smoke may cause serious short and long term effects on vegetation. Recent reports however, indicated that SO_2 may reduce several components of growth and yield in various species. These components include dry matter production, tillering, number of spikelets and grains, relative growth rate, root-shoot ratio and leaf area (Ashenden, 1978; 1979; Ayazloo, *et al.*, 1980; Davies, 1980). Increased concentration of SO_2 reduced fruit yield by 18% in tomatoes (Heggestard *et al.*, 1986). Sprugel *et al.*, (1980) studied the effects of SO_2 on yield and seed quality in field grown Soyabeans. The decrease in yield ranged from 48-50% due to decrease in seed weight and seed number per plants. Studies on wheat, rye, barely, pear and grape vine have shown that temporary accumulation of SO_2 in the atmosphere resulted in the decrease in yeild (Catanescu *et al.*, 1987). Both increase and decrease in the dry weight of seven wheat cultivars were observed by Laurence (1979), depending on the concentration and duration of exposure. Statistically significant increase in dry weights were found with six of the seven cultivars at low SO_2 concentration. Biomass production was increased on a dry weight basis. Crittenden and Read (1978) reported 36% decrease in growth and dry weight of *Lolium perenne*. *Vigna mungo* L. showed inhibition in growth parameters (Lalman and Singh, 1988) while significant increase in germination percentage was observed in *Zea mays* (Chand and Yadav, 1989). The SO_2 hindered the seed germination in radish, mustard, alfalfa and bajra, while the shoot growth of seedlings was adversely affected (Banerjee and Chaphekar, 1980). Satyanarayana *et al.*, (1985) reported a decrease in nodulation and dry matter production in pigeon pea due to SO_2. In *Vicia faba*, SO_2 interfered with nutrient uptake and plant growth, leading to reduction in root and shoot length, number of leaves and nodules and net primary productivity (Agrawal *et al.*, 1985). A transition from positive to negative effects has also been reported. The growth patterns indicated positive responses with low SO_2 exposure but negative responses pre-dominated with increasing concentration of SO_2. Faller (1971), Cowling and Lockyer (1976) reported that low concentration of SO_2 can stimulate plant growth by correcting nutrient sulphur deficiency. In contrast, there are many reports that degree of depression in yield and growth may be strongly influenced by many plant and environmental factors and age of plant (Ashenden and Mansfield, 1977; Cowling and Kozoil, 1978; Bell *et al.*, 1979; Bell, 1982).

Despite the numerous reports on the Indian crops, the literature pertaining to the impact of coal smoke pollution on leguminous crops growing in ambient conditions is very meagre.

Leguminous crops, supplying as much as 20-40% of edible grains, are claimed to be indispensable in tropical and sub-tropical regions of the globe. This applies to India in particular where majority of the population depends on vegetable protein. Legumes have no parallel in the green world as a source of biologically fixed nitrogen and as green manure for ameliorating degraded soils. It is estimated that 14-35 million tonnes of dinitrogen is fixed annually by symbiotic association in legumes. Recently the role of legumes has been further emphasized to descalate the acute problem of pollution due to indiscriminate use of synthetic fertilizers (Burman, 1990; Ray and Kumar, 1990).

However, these crops have remained neglected even in the era of "Green Revolution", that laid emphasis only on cereals to cope up with fast growing population. Consequently, in spite of the largest arable area of the world i.e. 22 million hectares, being occupied by grain legumes in India (Ramanujan, 1987), their cumulative yield is very low. This has resulted in the perpetual problem of wide spread protein malnutrition in the country.

The present work is an attempt in this direction to elucidate the effect of coal smoke pollution on plant growth, green area, phytomass accumulation, net primary productivity, yield, seed germination and repoductive capacity as well as the status of certain mineral balance, chlorophyll pigments, crotenoids, nitrogen, phosphorus, potassium and sulphur. The most important metabolic product protein content has also been studied in relation of coal-smoke pollution.

MATERIALS & METHODS

MATERIALS AND METHODS

Growth and biochemical responses and the net primary productivity of the selected pulse crops were studied in relation to coal smoke pollution, at different time intervals, in the following manner.

2.1 Selection of Pollution Sources

The Thermal Power Plant complex of Kasimpur has been selected as a source of pollution in the present work. The complex, one of the three major thermal power plants of Uttar Pradesh, is located in the Kasimpur town of Aligarh district, along the banks of the Upper Gangetic canal running in the North-West to South-East directio· The complex consists of three power stations namely 'A', 'B' and 'C' ('C_1' and 'C_2') having a capacity of 90 MW 210 MW and 230 MW electricity generation respectively.

2.2 Extent of Pollution

The whole complex runs on bituminous coal transported from various collieries of North India. The chief chemical constituents of the coal are 2.93% moisture, 22.17% ash, 31.86% volatile matters including 0.48% sulphur, 5.61% hydrogen, 5.23% nitrogen, 20.3% oxygen and 42.47% fixed carbon on an average (Table 1).

The data on coal consumption at the above source (Table 2) show that the average annual coal consumption

Table 1: **Chemical analysis of Coal collected from some important collieries of India (courtesy of AEE Thermal Power Plant Complex, Kasimpur)**

Name of collieries	% moisture	% Ash	% Volatile matters	% fixed carbon (by difference)	% sulphur	% hydrogen	% Nitrogen	% Oxygen	calorific value	Temperature of coal burning
Badjana	1.0	22.7	31.2	44.2	0.33	5.14	5.10	20.51	5717.1	1400
Bejdih	2.8	22.7	34.0	39.8	0.59	6.99	5.50	20.51	5888.8	1400
Centre Salgram	5.8	19.6	31.2	43.0	0.35	5.21	5.16	20.32	5906.0	14[illegible]
Kathara	2.1	20.6	30.6	46.1	0.56	5.14	4.96	19.86	5611.1	1400
Methani	3.0	22.2	32.8	41.4	0.55	5.74	5.46	20.40	5988.4	1400
Plidih	2.8	25.1	31.4	40.2	0.56	5.41	5.23	19.95	5547.7	1280
Average	2.9	22.7	31.8	42.5	0.48	5.60	5.23	20.30	5776.1	1380

comes to about 3,16,067 metric tons for plant 'A', 5,20,981 metric tons for plant 'B', 1,19,713 metric tons for plant 'C_1 and 2,08,308 metric tons for plant 'C_2'. The total annual coal consumption in all the power plants comes to be about 11,65,069 metric tons. The maximum coal is consumed in winter, which is followed by summer and monsoon seasons (Table 2).

When such huge amount of coal is subjected to high temperature (1200°C-1400°C) for combustion, it produces noxious gases, particulate matters and ash, released through the chimneys into the atmosphere. Table 3 shows the amount of CO_2, SO_2 and NO_2 in kg hour^{-1} and ppm hour^{-1} released from the source in different months and seasons, respectively.

2.3. GEOGRAPHICAL SET-UP

The Aligarh district lies in the North-West of Uttar Pradesh (Northern state of India) in the fertile agricultural area of Ganga Jamuna Doab between 27°29'N and 28°11'N latitude and 77°29'E and 78°38'E longtitude (Fig. 1). The Kasimpur town, the site of Thermal Power Plant Complex, lies in the Morthal pargana of the Koil tahsil in the Aligarh district. On the northern border of the town Upper Ganges Canal flows supplying water to the power plants. The place is about 16 km (road distance) in the north-west of the Aligarh city (Fig. 2A) situated between

Table 2: **Coal Consumption figure in the Thermal Power Plant Complex in Metric Tons (an average of three years data)**

Months	Power Station				Total monthly Consumption
	A	B	C1	C2	
November	34578	47632	2204	16570	100984
December	26558	45303	5682	20563	98106
January	26683	58685	22169	14790	122327
February	23735	50282	21142	19778	144937
March	20196	34611	29775	21948	106530
April	32095	35428	5475	10429	83427
May	28819	38582	2759	6208	76368
June	28882	44876	2629	19429	95816
July	25866	39861	9658	22562	97947
August	21405	49356	2697	18026	91484
September	18974	44301	5865	19856	88996
October	28276	32064	9658	18149	88147
Total in Winter (Nov.-March)	131750	236513	80654	76972	525889
Monthly Average	26350	47302	16194	15330	105177
Winter daily average	872.52	1566.31	536.24	507.64	3482.71
Total in Summer (April-June)	89796.00	118886.00	10863.00	54863.00	54575.00
Summer Monthly Average	29932.00	39628.70	10621.00	18191.70	91373.40
Summer daily Average	986.77	1306.44	119.37	599.73	3012.31
Total in Monsoon (July-Oct.)	54521.00	165582.00	27878.00	77079.00	365060.00

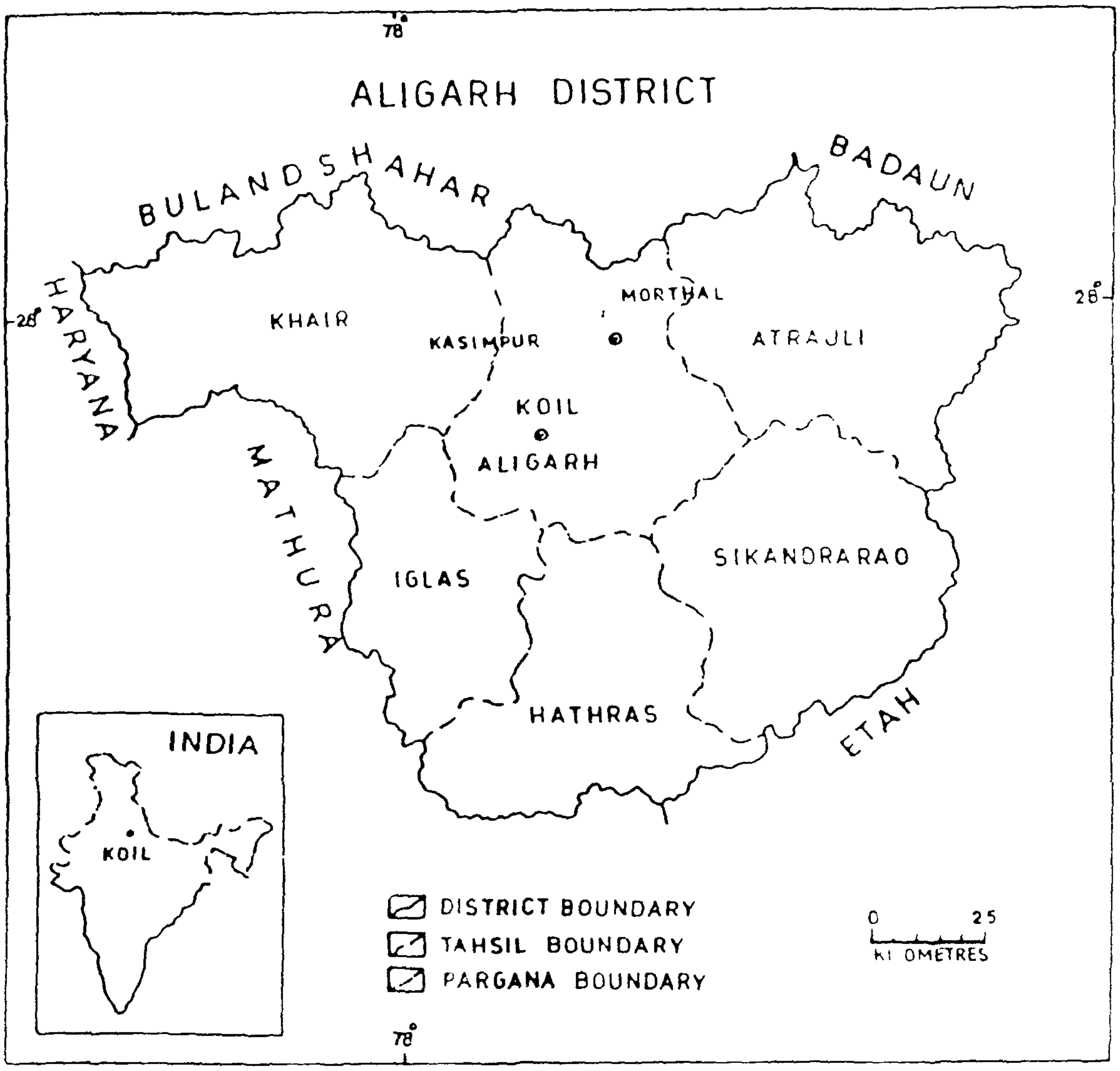
Monsoon Monthly Average	23630.30	41395.50	6969.50	19269.80	91265.00
Monsoon daily average	768.46	1346.20	226.65	226.66	2967.97
Annual Consumption	316067.00	520981.00	119713.00	208308.00	1165069.00
Average monthly Consumption	26338.9[illegible]	43415.08	9776.08	17359.00	97089.08
Average Daily Consumption	865.094	1427.35	327.28	570.71	3191.97

Source: Courtesy of AEE, Thermal Power Plant Complex of Kasimpur (only monthly data); Seasonal figures reproduced from the above data.

Table 3: **Amount of gases released from the Chimneys of the Thermal Power Plant Complex in different months (Average of three years)**

Months	Amount of SO_2		Amount of NO_2		Amount of CO_2	
	X10^5 Kg/hour	ppm/hour	X10^5 Kg/hour	ppm/hour	X10^5 Kg/hour	ppm/hour
November	0.111	0.011	1.994	0.199	21.843	2.184
December	0.098	0.010	1.766	0.177	20.536	2.054
January	0.128	0.013	2.290	0.229	25.604	2.560
February	0.126	0.013	2.264	0.226	26.636	2.664
March	0.122	0.012	2.184	0.218	22.299	2.230
April	0.115	0.011	2.057	0.206	10.845	1.084
May	0.114	0.011	2.038	0.204	15.985	1.598
June	0.135	0.013	2.412	0.241	20.738	2.074
July	0.127	0.013	2.268	0.2127	20.502	2.050
August	0.158	0.016	2.828	0.283	19.777	1.978
September	0.164	0.016	2.942	0.294	18.629	1.863
October	0.137	0.014	2.463	0.246	21.843	2.184
Winter Average (Nov.-March)	0.1170	0.0118	2.0996	0.2100	23.3836	2.3384
Summer Average (April-June)	0.1213	0.0121	2.1690	0.2169	15.8560	1.5856
Monsoon Average (July-October)	0.1465	0.0147	2.6253	0.2625	20.1878	2.0188
Annual Average	0.1279	0.0128	2.2922	0.2292	20.4364	2.0436

SOURCE: Courtesy of AEE, Thermal Power Plant Complex of Kasimpur.



78°
ALIGARH DISTRICT
BULANDSHAHAR
BADAUN
HARYANA
28°
KHAIR
KASIMPUR
MORTHAL
ATRAJLI
KOIL
ALIGARH
MATHURA
IGLAS
SIKANDRARAO
HATHRAS
ETAH
INDIA
KOIL
DISTRICT BOUNDARY
TAHSIL BOUNDARY
PARGANA BOUNDARY
0
25
KILOMETRES

FIG. I

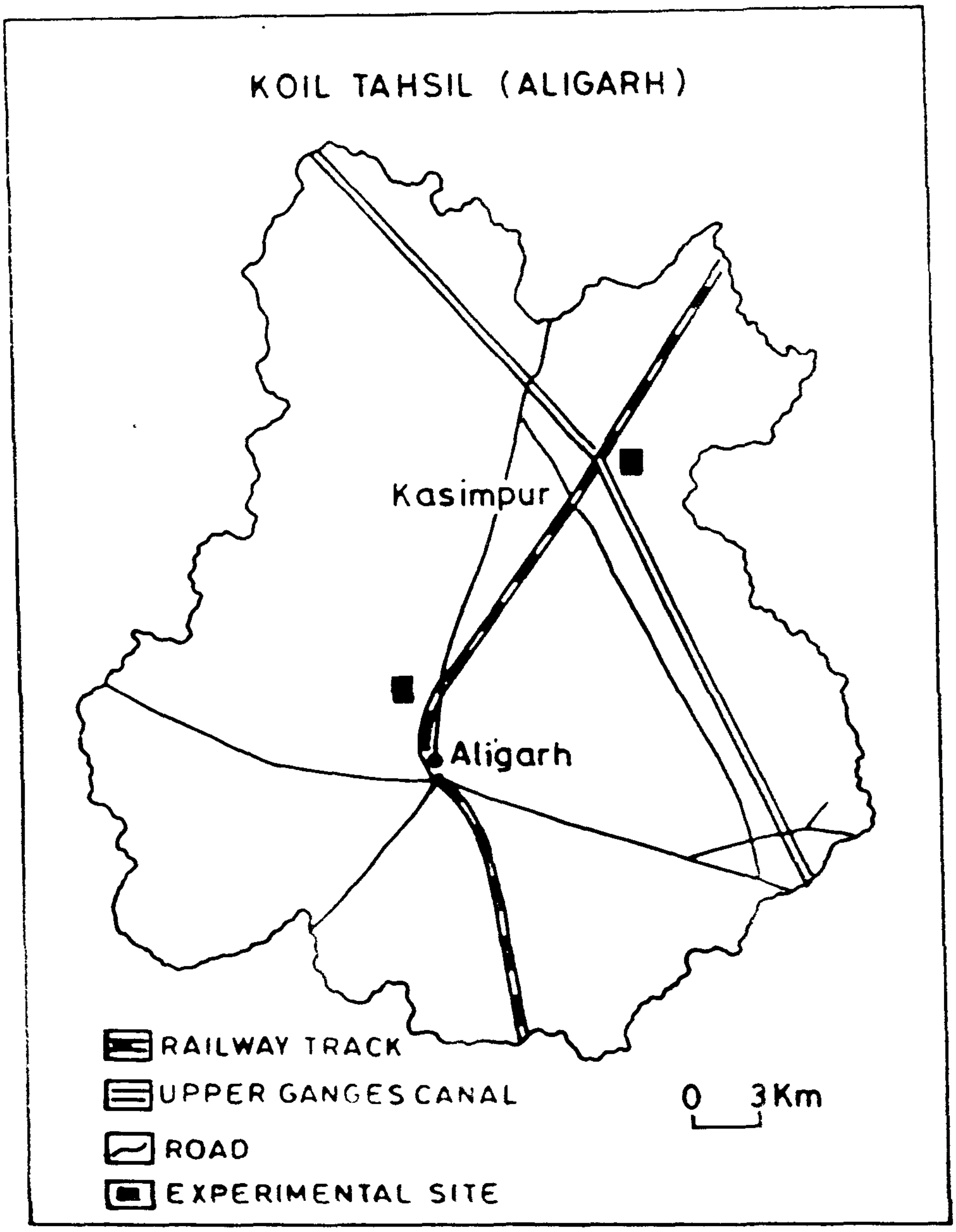

KOIL TAHSIL (ALIGARH)
Kasimpur
Aligarh
RAILWAY TRACK
UPPER GANGES CANAL
ROAD
EXPERIMENTAL SITE
0 3Km

Fig. 2A

27°59'N and 27°3'N latitude and 78°8'E and 78°93'E longtitude, about 187 meters above the sea level.

2.4 TOPOGRAPHICAL SET-UP

All the stations selected for the study have similar soil structure (Fig.2B)characterized by loam and clayey loam type of soil with a very high pH value and very poor drainage system (Table 4- 5) The layer of loam and clayey loam lies to the depth of 2.0 to 6.0 meter. from the surface. The quantity of clay is maximum in the top layers and it decreases downwards. The soil in this region is ash grey in colour, becoming black when moist.

2.5. Meteorology

Kasimpur and the surrounding areas have a dry and tropical monsoon type of climate with seasonal rhythm marked by the north-east to south-west monsoon. The year is divisible into three principal seasons viz. cold weather season (winter), hot weather season (summer) and rainy season (monsoon).

2.5.1 The Cold Weather Season / Winter (November to March)

The beginning of winter season is marked by a considerable fall in temperature. In this season, a relatively low pressure exists over the Indian seas, thus causing the winds to blow from plains towards the seas. The

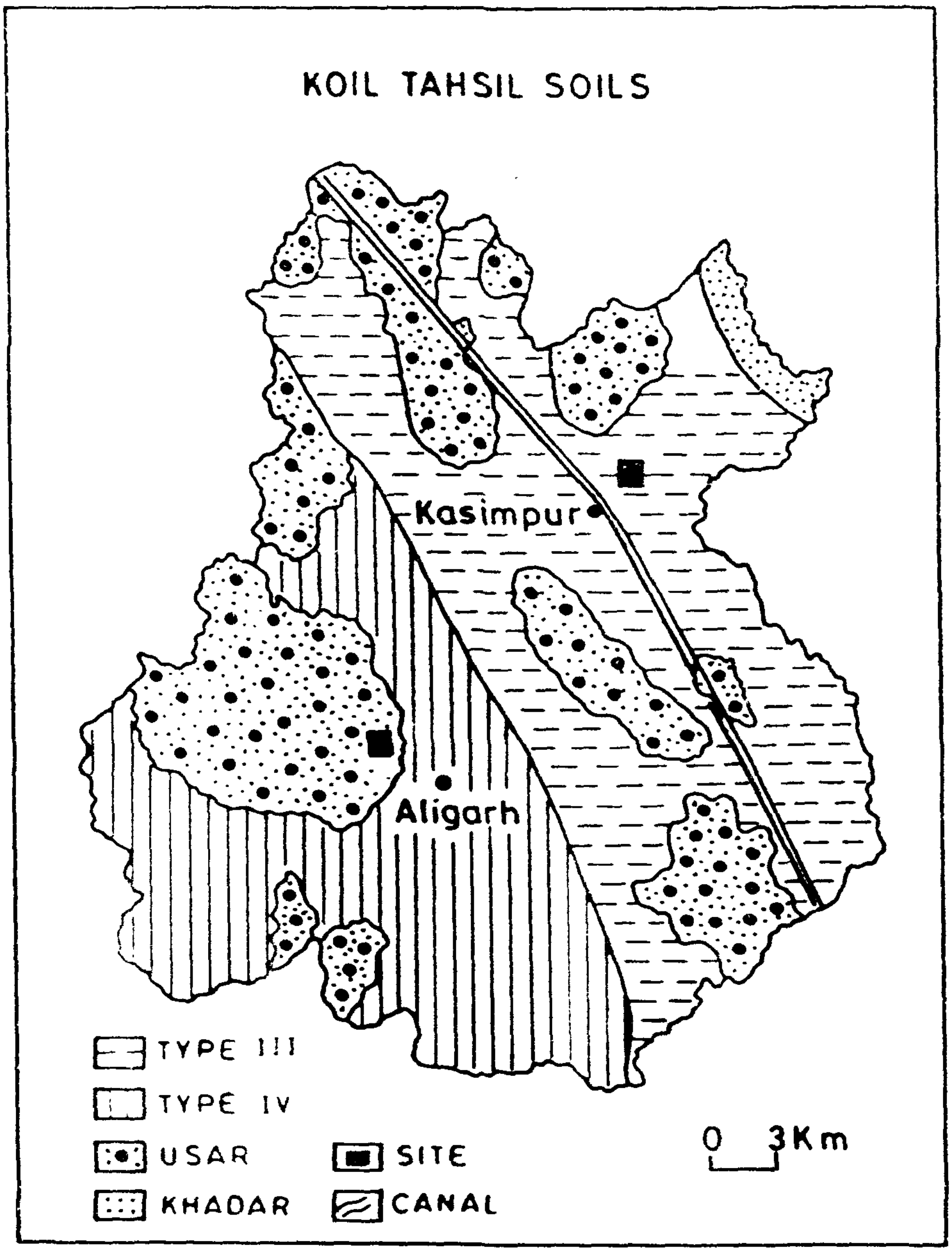

KOIL TAHSIL SOILS
Kasimpur
Aligarh
TYPE III
TYPE IV
USAR
KHADAR
SITE
CANAL
0 3Km

Fig.2 B

Table 4: Classification and traits of the kasimpur Soil (Aligarh type III Soil)

Soil type	Soil phase	Traits	Kasimpur Soil
Aligarh loam	Aligarh loam (Halomorphic)	Profile development	Mature
Aligarh Clayey loam		Colour	Ash grey-dark grey to Black
Aligarh Clay		Concretion	Kankar
		Sequoxides (Ca+Mg:Al)	High-more illuviation
		Lime	High more at bottom
		Soluble Sats	High
		Magnesia	Less than lime
		pH	7.6 to 8.6 or above
		Clay	No migration, maximum at the surface
		Drainage	Very poor

Source : Agricultural Directorate (Soil Survey and Research), Aligarh.

Table 5: Physio-Chemical and Mechanical analysis of soil samples collected in different seasons from various depths at Kasimpur

Season	Winter		Summer		Monsoon	
Depth (in cms)	0-15	15-30	0- 15	15-30	0-15	15-30
Physical Analysis (%)						
Moisture holding capacity	45.61	44.98	45.05	45.65	47.08	47.[illegible]
pH	8.20	8.20	8.90	7.04	6.43	8.40
Total exchangeable base	10.52	8.72	9.75	9.87	9.98	9.96
Exchangeable Ca	9.32	7.68	8.75	7.74	9.31	9.65
Exchange Mg	0.70	0.68	0.58	0.55	0.69	0.58
Exchangeable Na + K	0.50	0.46	0.42	0.26	0.48	0.47
Chemical Analysis						
Moisture Air	0.58	0.45	0.49	0.42	0.57	0.49
Loss of ignition	2.14	1.88	1.77	1.01	1.69	1.70
HCl insoluble	81.03	81.72	80.03	74.71	81.37	80.01
Sequioxides	12.20	11.10	11.35	10.76	11.39	11.46
Fe_2O_3	4.56	4.16	4.35	1.40	4.09	3.45
P_2O_5	0.09	0.09	0.083	0.08	0.075	0.096
Al_2O_5	7.55	6.85	6.13	6.29	6.59	6.31
CaO	1.26	1.96	0.98	0.57	0.97	0.98
MgO	0.47	0.54	0.46	0.59	0.99	1.00
K_2O	0.57	0.68	0.63	0.65	0.68	0.71
CO_2	0.57	1.29	1.15	1.35	1.21	1.25
Water soluble salts	0.071	0.669	0.075	0.072	0.081	0.081
Carbonates (Na_2CO_3)	Nil	0.009	0.003	1.001	0.008	0.007
Bicarbonates ($NaHCO_3$)	0.052	0.035	0.047	0.050	0.048	0.047
Total Nitrogen	0.075	0.071	0.075	0.073	0.079	0.063
Chlorides (NaCl)	0.011	0.015	0.018	0.017	0.017	0.017
Sulphate (Na_2SO_4)	4.13	4.10	Nil	Nil	5.73	5.22
Mechanical Analysis						
Sandy coarse sand	1.40	1.13	1.27	1.79	1.35	1.43
Fine sand	46.98	51.99	59.35	42.89	52.31	52.01
Silt	22.13	20.05	21.01	21.00	20.37	21.76
Clay	22.04	22.25	21.56	21.38	22.70	22.56

Source: Agricultural Directorate (Soil Survey and Research), Aligarh.

mean maximum temperature is 27.11°C in November and 30.14°C in March, while the average minimum temperature for these months is 12.98°C and 14.63°C respectively (Fig.3). It is very cold in the month of January (7.87°C - 21.32°C), the temperature begins to rise (14.63°C-30.14°C) in March. In winter months the nights are very cold and the days are comparatively warmer with foggy mornings.

Wind direction during the winter season is predominantly from east to west, west to east or south east to north east. The winds during this season are light and blow at an average speed of 3.06km/hour(Fig. 6A). The average relative humidity during this season is 49%,57.5% 61%,52% and 38.5% for months November to March respectively (Fig.5). The rainfall in this season is irregular and sporadic (Fig.4).

The Hot Weather Season/Summer (April to June)

This season extends form March to June. It begins with an appreciable rise in temperature and a decrease in pressure. Due to wide range of temperature during the summer months, days are warm and nights are pleasant. The minimum and maximum temperatures in April are 19.01°C and 37.01°C respectively. The temperature continues to rise during May (23.29°C-39.50°C) and June (26.60°C-40.86°C) (Fig.3). Days are hot and dry, the average relative humidity declining to

30%,35% and 44.5% in the months of April,May and June, respectively (Fig.5). The hot day winds blowing with high velocity form a regular phenomenon. The velocity of wind begins to increase steadily from April with an average wind speed of 4.31 km/hour (Fig.6B). The wind speed rapidly increases during 8 am to 1 pm causing the wind to blow almost with the force of gale during the next 2-3 hours. It then falls suddenly by 6 pm and a calm usually prevails during the night.

Dust and thunder storms are frequent, at times accompanied by rains. The rains are rare, sporadic, short lived and highly variable in amounts. The average monthly rainfall is about 0.75 mm for April, 14.4 mm for May and 23.60 mm for June respectively (Fig. 4).

The Rainy Season/Monsoon (July to October)

The atmospheric temperature falls with the arrival of the humid oceanic currents and the air becomes cool and pleasing by the end of June. The average minimum and maximum temperatures fall to 24.84°C - 34.48°C in July, 24.79°C-33.38°C in August, 22.54°C-33.60°C in September and 18.46°C to 33.47°C in October (Fig.3). The average relative humidity is 72%, 75%,70% and 52% for these months respectively (Fig.5). The sky is generally overcast. Rain set is usually by the end of June or early July and continues untill the

Fig. 3 The graph shows monthly temperature in centigrade (Average of years 1991-1993)

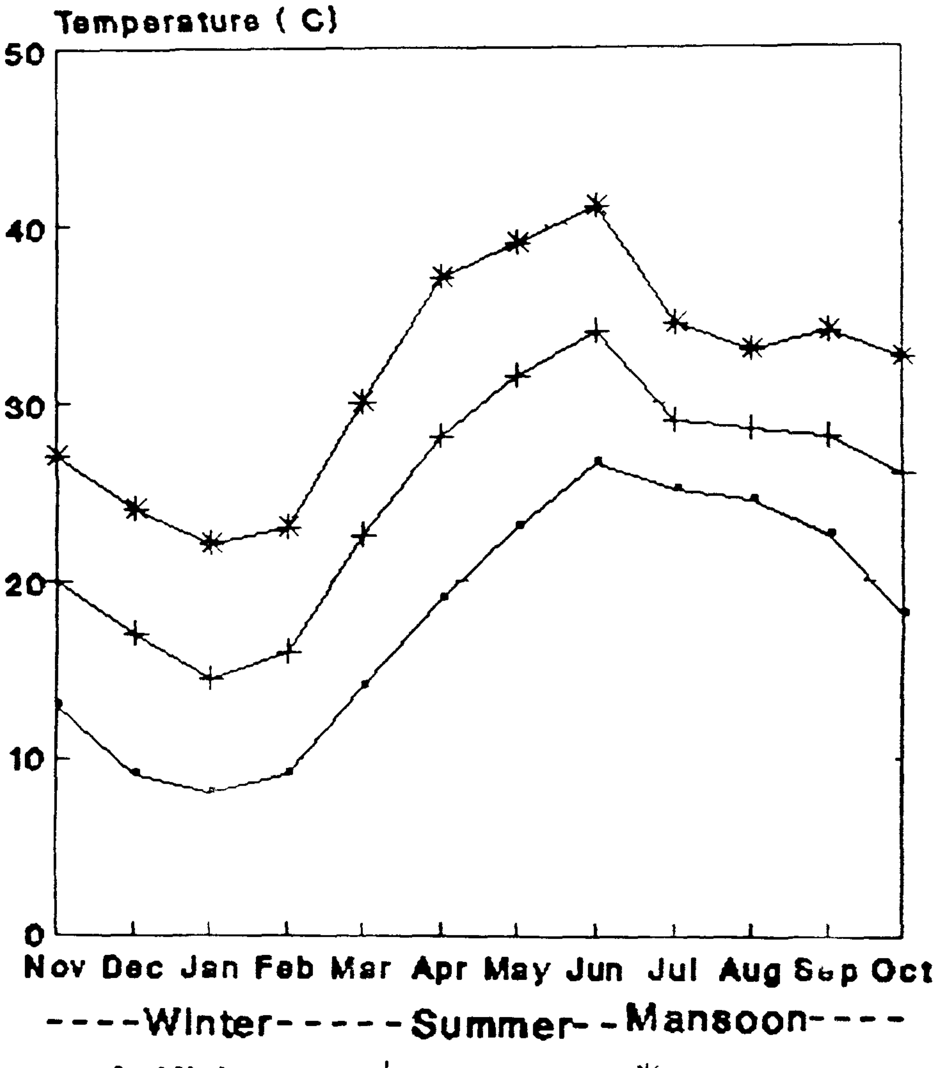


Fig. 4 The graph shows monthly rainfall in mm (Average of years 1991-1993)

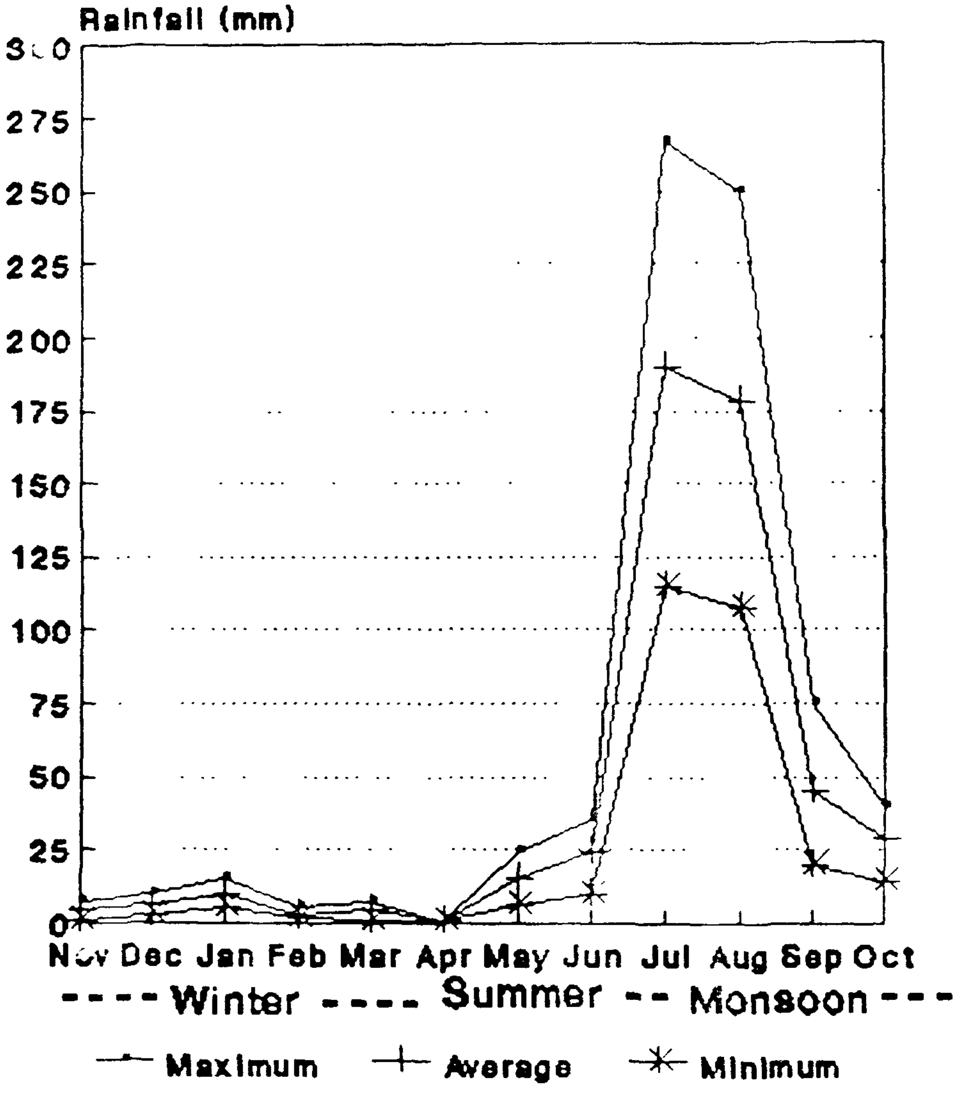
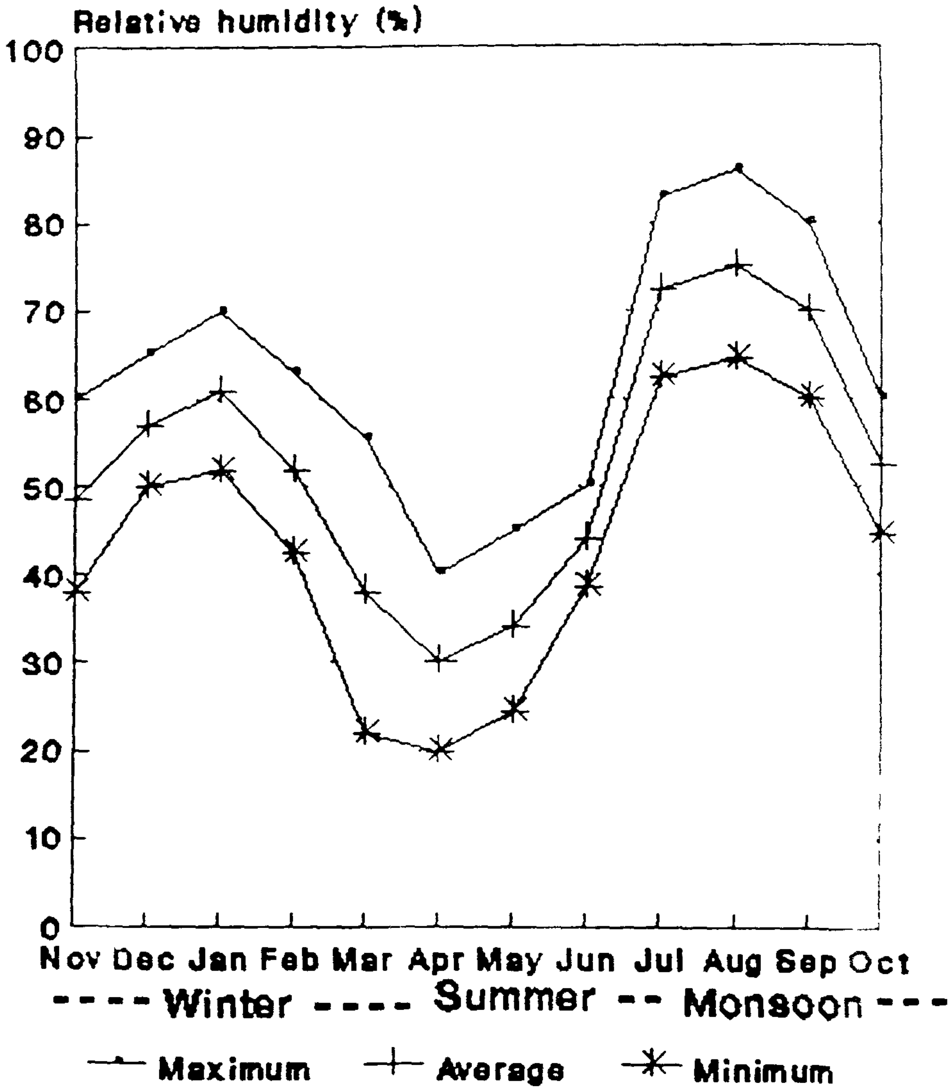


Fig.5 The graph shows monthly relative humidity in percentage (Average of years 1991-1993)



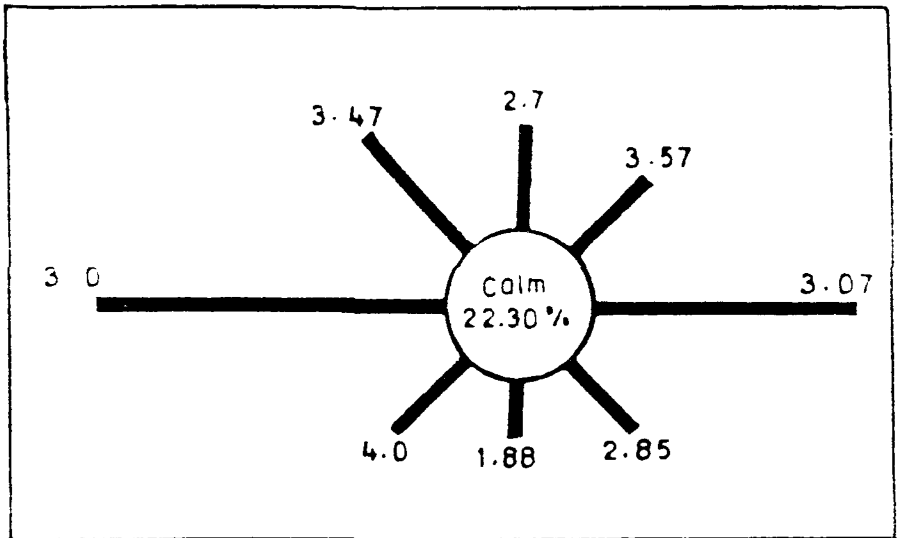
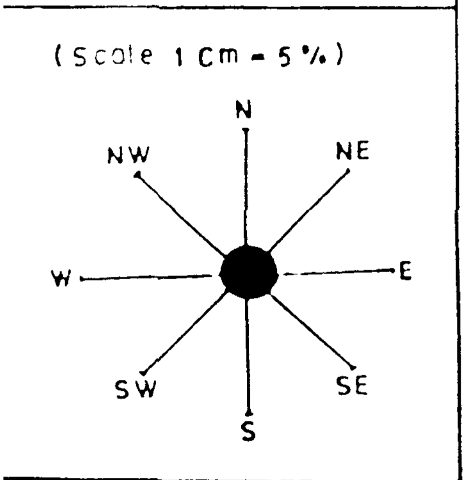


FIG. 6A: VELOCITY & PERCENTAGE OF WIND DIRECTION DURING WINTER SEASON



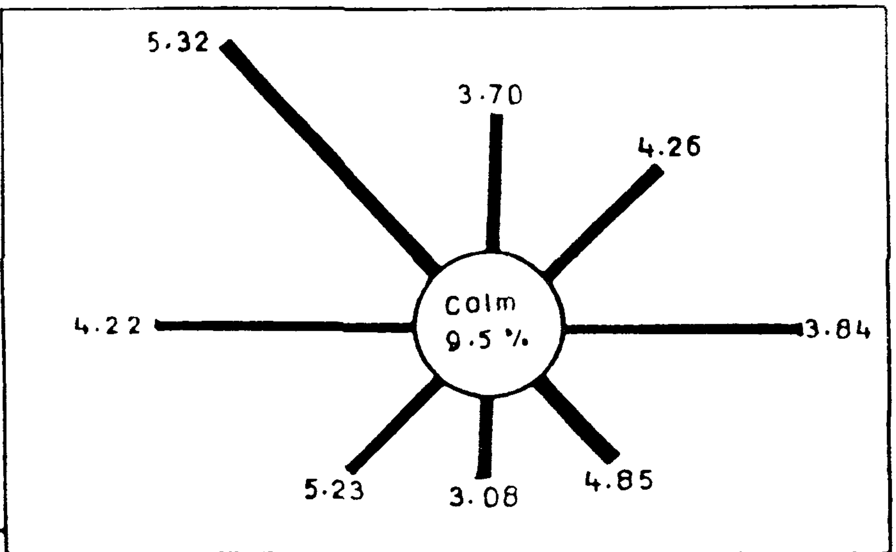


FIG. 6B: VELOCITY & PERCENTAGE OF WIND DIRECTION DURING SUMMER SEASON

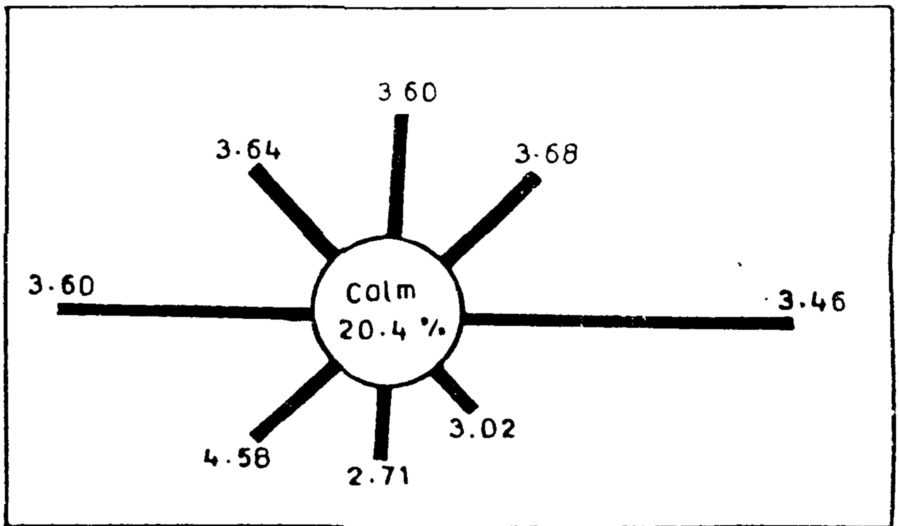


FIG. 6C: VELOCITY & PERCENTAGE OF WIND DIRECTION DURING MONSOON SEASON end of September or early October. The average maximum rainfall (about 191 mm and 177.5mm) was observed the months of July and August respectively(Fig.4). During this season winds blow pre-dominantly from east-west, to west-east, and to south-west to north-east, to south-west and to south-east to north-west(Fig.6C) with an average speed of 3.54 km/hour.

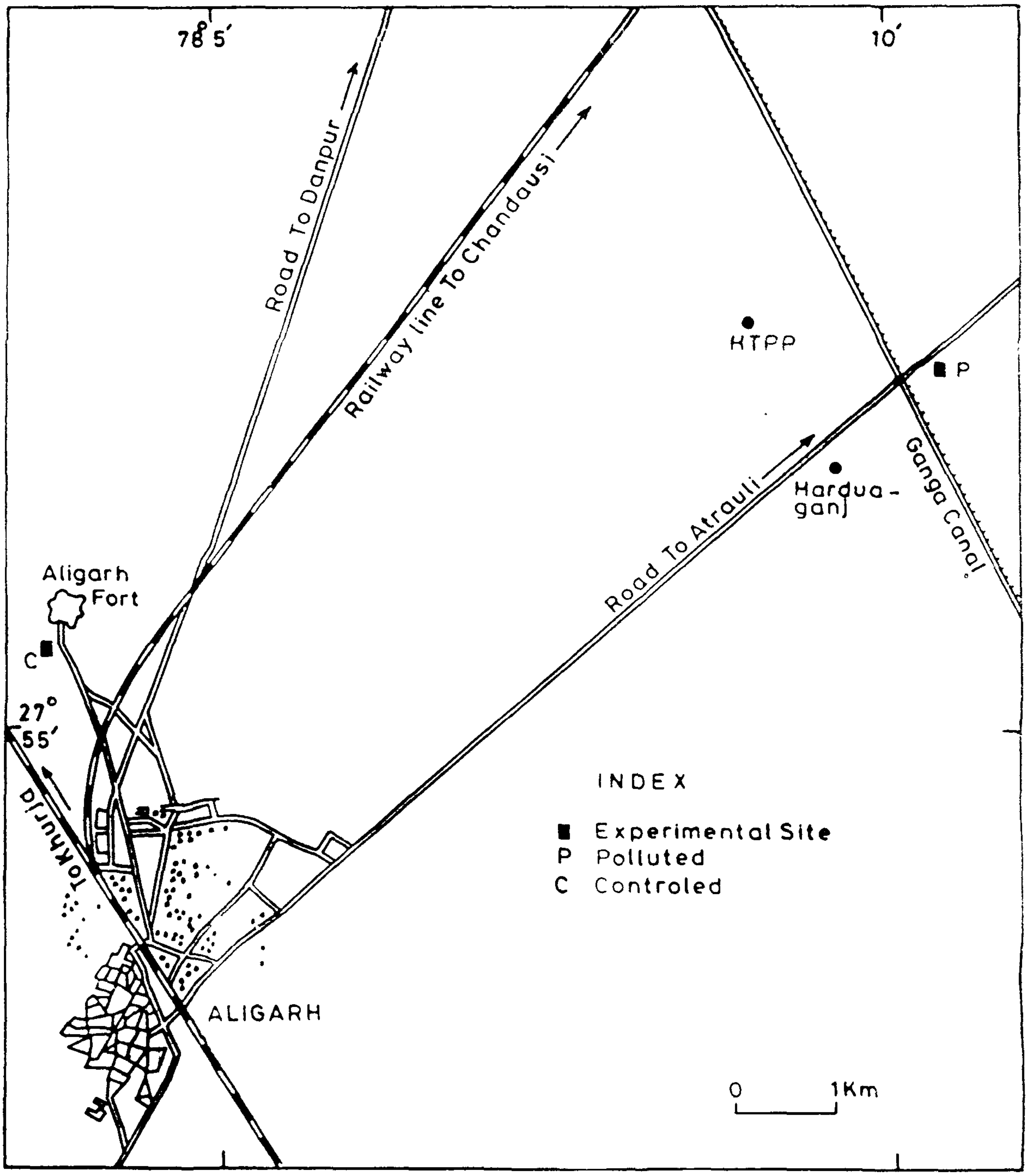
2.6 Selection of Sites

Cultivated fields were selected as sites for the present study, at a distance of 2 k.m. from the source of pollution on windward direction (site P). A control site (c) was maintained at the botanical garden of Aligarh Muslim University, situated at 16 km from the thermal power plant complex (Fig.7)

2.7 Selection of Plant Species

The following pulse crops were selected for the present study:

Species	Variety	Crop duration
1. *Cicer arietinum* L.	'T3'	120 days
2. *Lens culinaris* L.Medic	K-75	90-100 days
3. *Pisum sativum*. L.	Arkel	120 days



78°5′
10′
Road To Danpur
Railway line To Chandausi
HTPP
P
Harduaganj
Ganga Canal
Road To Atrauli
Aligarh Fort
C
27° 55′
To Khurja
INDEX
Experimental Site
P Polluted
C Controled
ALIGARH
0 1Km

Fig.7

2.7.1 Cultured Practice

2.7.1.1 Cicer arietinum L. cv. T_3

Normal agricultural practice has been followed for preparation of the field. The seeds were sown in rows directly in the field in mid October. The rows were maintained 20-30 cm apart and sowing was done at 7-10 cm, depth, at the rate of 95 kg per hcctare.

The crop does not need a regular weeding as, .. suppresses weed growth. In the present study weeding was done only once during the first 4-6 weeks. The crop was irrigated only once at 45 days stage. The crop matured by 120 days.

2.7.1.2 Lens culinaris and L. Medic cv. K-75

This is grown as a cold weather unirrigated crop. The sowing season of lentil extends from October to December. It is generally cultivated alone. Lentil resembles gram a great deal in plant habit and cultivation requirements. The preparation of land in the present study was done by two ploughings after the rainy season. The seeds were sown in rows of 20-30 cm apart at the rate 80 kg per hcctare. The crop normally does not require manure, weeding or interculture. However, in the present study weeding was done at 45 days old stage. Only one irrigation was provided when the crop was 45 days old. The crop matured by 90-100 days. It was harvested before it was dead ripe, and dried for about a week. The average grain yield of the selected variety K-75 is 1000kg per hectare under irrigated condition.

2.7.1.3 *Pisum sativum* L. cv. Arkel

It is also grown as a cold weather irrigated crop. The sowing season extends from October to December. This pulse is similar to gram and lentil in its requirements, except that a finer seedbed is needed, it does better in loamy soils. It can not be grown in alkaline soils. Seed is sown in rows 30-45 cm apart, at the rate of 100 kg per hectare. The crop generally receives no manure, weeding or interculture and matures in 120 days. The average grain yield is 800kg per hectare under the local condition. This pulse is similar to gram and lentil in all its requirements. The crop, however, can not withstand continued frost especially during flowering and pod formation. Therefore the crop which received irrigation at flowering time, is procted against frost to a great extent.

2.8 PARAMETERS

The following parameters were selected to work out the responses of the selected crops to air pollution caused by coal smoke:

2.8.1 Growth Activity

(a) Shoot length (cm)

(b) Root length (cm)

(c) Growth index

2.8.2 Green Area

(a) Number of branches per plant.

(b) Number of leaves per plant.

(c) Number of leaflet per leaf

(d) Area per leaflet

(e) Area per leaf

(f) Total green area per plant

2.8.3 Biomass

(a) Shoot biomass

(b) Root biomass

(c) Phytomass

(d) Net primary productivity(NPP)

2.8.4 Reproductive Growth

(a) Number of flowers per plant.

(b) Number of fruits per plant.

(c) Number of seeds per pod.

(d) Number of seeds per plant.

(e) 100-seed weight.

(f) Harvest index.

(g) Seed viability

(h) Seed germination.

(i) Reproductive capacity.

2.8.5 Biochemical Responses

(a) Photosynthetic Pigments

(b) Protein

(c) Sulphur

(d) Nitrogen

(e) Phosphorus.

(f) Potassium.

To study the plant height, the shoot and root lengths were measured in centimetre (cm). The shoot length covered the plant axis from the ground level to the upper most growing tip of the main axis. The root length was measured from the ground to the root tip level.

2.8.6 Growth Index

Growth index was calculated applying the formula :

Growth index=

$$\frac{\text{Growth (cm per day) in the presence of coal smoke pollution}}{\text{Growth (cm per day) in control}}$$

Green Area

(a) Number of branches per plant

Ten replicates were taken to count the number of branches in each selected species at different intervals.

(b) Number of leaves per plant

The number of fully opened leaves were recorded, at regular intervals out of ten randomly selected individuals per species.

(c) Number of leaflet per leaf

There were ten replicates, to count the number of leaflet per leaf per species.

(d) Leaflet area and total green area per plant

The outlines of the randomly selected 20 leaflets were drawn on a tracing paper. The areas occupied by these drawing were measured with the help of a planimeter. The average area of a single leaflet was multiplied by the total number of leaflets per leaf. The average leaf area was multiplied by total number of leaves per plant to obtain the total green area of leaf in m^2.

Biomass (Plant product on dry weight basis)

To find out the biomass of shoot and root, the samples of selected species were oven dried at 80°C for 48 hours, and dry weight in grams was determined on a chemical balance.

Phytomass

For phytomass determination the individual plants were dug out from the field keeping the root system intact. These were throughly washed to remove the soil particles. The fresh plant samples were oven dried at 80°C for 72 hours and weighed to obtain the phytomass value.

$$\text{Phytomass} = \frac{\text{Dry weight of whole plant with roots}}{\text{Age of plant}}$$

Net Primary Productivity

Net primary productivity was calculated by taking the differences between successive phytomass values and dividing by the period between them.

Number of flowers, fruits and seed per plant

In all cases flowers, fruits and seeds per plant were counted on their appearance at regular intervals out of 10 randomly selected plants per species.

Seed weight

Seeds were sun dried for a week and weighed on a chemical balance. In each case 100 seeds were selected at random basis from each individual using 10 replicates for each species.

Harvest index It was calculated as follows :

$$\text{Harvest index} = \frac{\text{Weight of seeds per plant}}{\text{Phytomass of plant}}$$

Seed viability

The pre soaked seeds were finally cut into two equal parts for exposing the embryo and treated with one percent solution of 2,3,5 triphenyl tetrazolium chloride. Care was taken to avoid direct exposure to sunlight or prolonged diffused light, as this reagent is light sensitive. The reaction was completed in 7-8 hours in dark at room temperature. Almost colourless solution of tetrazolium salt was transformed in the insoluble bright red triphenyl formazan. Stained seeds were counted as viable (Kuhn and Jerch el (1941).

Seed germination

Seeds were soaked in water for 12 hours. There were five replicates of 100 seeds each and were kept in petridishes lined with filter paper and kept moist with water. Observations were recorded daily.

Reproductive capacity

The reproductive capacity was calculated using the formula given by Ambasht (1986).

$$R.C. = \frac{\text{Seed output} \times \text{No of seed germinated}}{100}$$

Biochemical Analysis

Photosynthetic pigment

The fresh leaf samples after being brought to the laboratory were removed from the ice bags and their surface gently cleaned with moist cotton to remove any particulate matter deposited over them. The ch lorophyll content was estimated by following the method of Arnon (1949). One gram fresh sample was crushed gently with 80% acetone in a mortar and pestle. To this was added a little pinch of calcium carbonate ($CaCO_3$). The sample after being ground to a fine pulp was centrifuged (5000 rpm for 5 minutes) and the supernatant was transferred to a 100 ml volumetric flask. The residue was repeatedly ground and centrifuged till it turned colourless, thus ensuring the complete extraction of chlorophyll from the tissue. The volume of the extract was made 100 ml by adding 80% acetone. The absorption of the solution was read at 663, 645, 510 and 480 nm on spectrophotometer. The chlorophylls (a and b) and carotenoid contents were analysed by applying the formulae given by Maclachlan and Zalik (1963) and Duxbury and Yentsch (1956) respectively. The total chlorophyll was estimated by applying the formula given by Arnon (1949).

$$\text{mg chlorophyll 'a'/ g tissue} = \frac{12.3\ D663 - 0.86\ D645}{d \times 1000 \times W} \times V$$

$$\text{mg chlorophyll 'b'/ g tissue} = \frac{19.3\ D645 - 3.60\ D645}{d \times 1000 \times W} \times V$$

$$\text{mg carotenoids / g tissue} = \frac{7.6\ D480 - 1.49\ D510}{d \times 1000 \times W} \times V$$

$$\text{mg total chlorophyll / g tissue} = \frac{20.2\ D645 - 8.02\ D663}{d \times 1000 \times W} \times V$$

where D663, D645, D510 and D480 represent the values of optical densities at the respective absorption spectra.

V = Final volume of chlorophyll extract in 80% acetone.

W = fresh weight of tissue extracted.

d = length of the light path.

Nitrogen

The oven dried samples were powdered and passed through 72 mesh screen. The samples were then digested by following the method of Lindner (1944).

Digestion of Samples

100 mg dry powder of the sample was taken in a 50 ml *Kjeldahl flask. Two ml of pure H_2SO_4 (BDH)* was added and the mixture was heated for about two hours to dissolve the powder. This acid turned the contents black. After cooling the flask for about 15 minutes, 0.5 ml of chemically pure 30% hydrogen peroxide was added dropwise. The solution was again heated for about 30 minutes, until it turned light yellow in colour and then cooled with 3-4 drops of H_2O_2 added, it was reheated for about 15 minutes to get a clean extract. Excess of hydrogen peroxide was avoided.

Estimation of Nitrogen

A 10 ml aliquot of the peroxide digested material was transferred to a 50 ml volumetric flask. To this, 2 ml of 2.5N sodium hydroxide was added to neutralize the excess of acid partially. To prevent turbidity, one ml of 10% sodium silicate was added to the flask and the volume made up. In a 10 ml graduated test tube, 5 ml of aliquot of this solution was taken and 0.5 ml of Nessler's reagent was added and followed by thorough shaking. The final volume was made up with DDW and kept for about 5 minutes for the maximum colour development. This solution was taken in colorimetric tube and its optical density measured at 525 nm on a "spectronic-20 colorimeter". A blank was run simultaneously during determination. A standard curve of known dilution of ammonium sulphate solution was made and the reading of each sample compared with the calibration curve. Nitrogen in each sample was calculated in terms of percentage on dry weight basis.

Phosphorus

The samples were digested by following the method of Lindner (1944), (as described in case of Nitrogen) and phosphorus was estimated by the method given by Fiske and SubbaRow (1925) in the aliquot. In a 10 ml graduated tube, 5 ml of aliquot of peroxide digested material was taken and 1 ml molybdate reagent was added carefully, followed by 0.4 ml of Amino-naphthol-sulphonic acid solution. The colour of the solution turned blue and its volume made upto 10 ml with double distilled water. The solution was shaken well and allowed to stand for 5 minutes for maximum colour development. The solution was transferred to a colorimetric tube and per cent transmittance was read at a 620 nm, on a "Spectronic-20" colorimeter. The standard curve was plotted by using known dilutions of monobasic potassium phosphate solution.

Potassium

The samples of leaves, were digested by the method of Lindner (1944) as described in case of Nitrogen. The potassium contents in the samples were estimated flame photometrically. One ml of aliquot (peroxide digested material) was suitably diluted with double distilled water in a graduated tube. A blank containing only distilled water was run simultaneously. The readings were compared with a calibration curve plotted using the known dilutions of a standard potassium sulphate solution. The potassium was expressed on percent basis.

Sulphur

For the estimation of sulphate-sulphur, the method given by Patterson (1958) was adopted . The oven dried samples were ground and passed through 72 mesh screen. 300 mg screened powder and 0.1 ml selenium dioxide (SeO_2) solution was digested using 10 ml conc. HNO_3 and 1 ml of conc. HCl. After filtering the digested material, 10 ml of 3% glycerol was added and volume made upto 100 ml with distilled water. To this solution 5 ml of 2% barium chloride ($BaCl_2$) solution was added to precipitate sulphur as barium sulphate ($BaSO_4$). The optical density was noted at 420 nm on a spectrometer. The amount of sulphur was determined by freshly prepared standard curve with potassium sulphate solution.

Protein

The protein content in the seed was estimated by following the methods of Lowry *et al.* (1951). Seeds were ground and passed through 72 mesh screen. One gram screened powder was homogenised with 5-10 ml of phosphate buffer (pH 7-9) in a glass mortar.

The solution was centrifuged and the supernatant was used for protein estimation. 0.1 ml and 0.2 ml of the sample extracts was pipetted out in two graduated tubes and volume made upto 1 ml in each tube. Another tube with 1 ml of water served as blank. To each of these test tubes was added 5 ml of Reagent C. The solution was mixed well and allowed to stand for 10 minutes. Then 0.5 ml of Reagent D was added to this solution in each tube and incubated at room temperature in dark for 30 minutes . The blue colour developed was read at 660 nm on a "spectronic-20" colorimeter. The protein content was estimated by comparing the optical desnsity of each sample with a calibration curve plotted by taking known dilutions of a standard solution of bovine serum albumin.

2.9 STATISTICAL ANALYSIS

The data collected on different parameters pertaining to the growth performance of selected pulse crops carried out at different study sites are statistically analysed as under to determine the degree of authenticity of results.

Mean (X)

The arithmetic mean is computed by taking the sum of a number of values (X_1, X_2,X_3.....and so on), and dividing it by the total number of values (N) involved., Thus,

$$X = \frac{(X_1 + X_2 + X_3 + \ldots\ldots\ldots X_n)}{N}$$

$$X = \frac{\Sigma X_n}{N}$$

Where $X_1, x_2, x_3 \ldots\ldots\ldots x_n$ = observations

N = number of observations involved.

Standard Deviation (δ or S.D.)

Standard deviation is a measure of fluctuations in a sample produced as a result of chance factor's of sampling from the same population. It is calculated by the following formula, for each parameter of the study.

SD for large samples

$$SD = \pm \frac{\sqrt{(X-X_1)^2 + (X-X_2)^2 + \ldots\ldots(X-X_n)^2}}{N}$$

SD for small samples :

$$SD = \pm \frac{\sqrt{(X-X_1)^2 + (X-X_2)^2 + \ldots\ldots(X-X_n)^2}}{N-1}$$

Where, X = Mean of the observations involved.

$X_1, X_2, X_3 \ldots\ldots\ldots =$ observations.

N = number of observations involved.

Per Cent Variation (P.V.)

To show and compare relative variabilities of two or more sets of measurements entirely in different units, P.V. is calculated. Percent variation of any parameter, a unitless number, measures the magnitude of variation present between the mean of the two sites, relative to the average of the site selected as base for the comparison. It was obtained and summarised as follows :

Formula used for Per cent Variation between different sites.

$$\text{Percent variation} = \frac{X_c - X_p}{X_c} \times 100$$

Where X_c and X_p are the arithmetic means of the parameters at sites control and polluted respectively.

Test of Significance

The test of significance is a device to find out whether or not an observed pair of means differs significantly from each other, or this differences is just a result of chance influence. It is a device, a criterion, to arrive at a judgement and confidence about the validity of a result. The following two tests are applied for the purpose.

Student t-test

It is applied to test the significance of the difference between the two sample means (if any), each sample collected from the two study sites.

The following formula is used to compute t-values which is compared with the table value of 't' at their particular degrees of freedom. If calculated 't' exceeds the table value the difference between the two samples is treated as significant, otherwise the difference is attributable to chance factor.

$$t = \frac{\text{Difference of two sample means}}{\text{Standard error of the difference}}$$

$$t = \frac{X_1 - X_2}{\sqrt{\dfrac{(S.D_1)^2}{N_1} + \dfrac{(S.D._2)^2}{N_2}}}$$

where, X_1 = Arithmatic mean of one sample

X_2 = Arithmatic mean of the other sample

$S.D._1$ = S.D. of one sample

$S.D._2$ = S.D. of other sample

N_1 = NO. of observation of one sample

N_2 = No. of observation of other sample.

Degree of Freedom (D.f.)

Degree of freedom, to be applied to the number of data particularly in t-test is calculated as follows:

$$D.F. = N_1 + N_2 - 2$$

where, N_1 = No. of observations of one sample

N_2 = No.of observations of other sample

For its use in the least significant difference analysis (L.S.D.).

OBSERVATIONS

3. OBSERVATIONS

3.1 GROWTH ACTIVITY

The growth activity of the selected crops has been studied for a period of 100 days at an interval of 20 days, in crops raised in experimental and control sites. The observations recorded are statistically analysed, in order to know the significance of the results by using simple t-test.

3.1.1 Shoot Growth

The shoot growth has been recorded in different growth stages of plants starting from 20 days old seedlings to the harvest stage. The results obtained are summarized in Table 7. A glance on the data shows that the exposure of seedlings to coal-smoke pollution did not affect the growth activity of *C.arietinum* upto 20 days, although there occurred an apparent increase in the shoot growth in the polluted site. In 40 days old crop, the polluted site significantly decreased the growth activity of the plants compared to control site, causing 27.7 per cent decrease. In the third stage of observation i.e. on 60 days old plants the activity has been highly hampered by pollution hazard, recording a 19 per cent loss in shoot length which on statistical analysis has proved to be highly significant. In the other two stages also i.e. 80 and 100 days old plants, the shoot length of this species recorded a highly significant loss amounting upto 30 per cent compared to control.

In case of *L.culinaris* at the first stage of growth, there was a marginal decrease in shoot length amounting upto 11 per cent under the coal smoke pollution and at 40 day sold crop, the plants gained a 16 per cent increase over the control. In the last three stages i.e. at 60, 80 and 100 days old crop, the plants facing coal-smoke pollution, recorded a highly significant decrease in shoot length amounting up to a maximum of 30 per cent at 80 days old stage. The growth activity of *P.sativum* recorded an initial significant gain upto 40 days followed by a significant decrease in shoot length, from the flowering. A comparison of all the three at seeding stage under the influence of coal-smoke pollution, shows that *P.sativum* is the only species which gained a significant increase in shoot length upto 40 days, while *L.culinaris* showed a significant loss and *C.arietinum* a non-significant loss respectively. In the pre-flowering stage of 40 days, the behaviour of all the crops except *C.arietinum* showed a similar trend in having a significant increase in shoot length over the control under the coal smoke pollution. In the last three stages of growth all the species suffered from pollution hazard, recording a highly significant loss in shoot length.

Table 7: **Data on Shoot length (in cm.) at different intervals in the selected species at polluted and control sites**

		Days after sowing				
Species	Site	20	40	60	80	100
C. arietinum	P	13.0±1.7	26.00±2.5	29.00±2.7	30.00±2.7	30.00±4.0
	C	12.0±1.8	36.00±2.5	36.00±2.3	41.00±2.2	43.00±3.3
	P.V.	+(8) N.S.	-(27.7)**	-(19)**	-(27)**	-(30)**
	G.I.	1.0833	1.1403	0.8055	0.6555	0.697
L. culinaris	P	9.00±0.87	22.00±2.7	28.00±3.6	30.00±2.6	30.00±2.6
	C	10.00±0.92	19.00±2.6	38.00±2.5	43.00±5.2	40.00±5.3
	P.V.	-(11)*	+(16)*	-(26)**	-(30)**	-(25)**
	G.I.	1.111	1.170	0.736	0.698	0.750
P. sativum	P	15.0±1.9	21.00±2.7	26.00±4.6	33.00±3.5	36.00±4.8
	C	13.0±1.8	18.00±2.3	32.00±2.6	42.00±3.9	50.00±3.3
	P.V.	+(15)*	+(17)*	-(19)**	-(21)**	-(28)**
	G.I.	1.154	1.166	0.812	0.785	0.720

Value are means ± standard deviation
* Significant at $p < 0.05$ level.
** Significant at $p < 0.01$ level.
N.S. Non significant.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

The growth index calculated on the basis of the formula:---

$$\text{Growth index} = \frac{\text{growth in the presence of coal smoke-pollution}}{\text{growth in the control}}$$

showed that it was more than one up to 40 days and less than one from 60 days to 100 days (Table 7).

3.1.2 Root growth

The growth activity of roots in the selected crops was studied at 20 days interval for a period of 100 days. The data obtained on root growth are shown in Table 8. In *C.arietinum*, the root growth suffered a severe loss at all stages of growth except the first stage in which the decrease in length due to coal-smoke pollution was only marginal and non significant. Almost a similar result regarding root length has been obtained in case of *P.sativum* Table 8. However in case of *L.culinaris*, the root growth showed a non-significant increase in the first stage and significantly severe losses in the subsequent stages of growth, record a maximum loss of 32 per cent at [illegible] days old crop. Growth index calculated in the different stages of root growth on the same basis as in the case of shoot length had shown that the index was invariably less than one in all the three crops, indicating a severe loss due to coal-smoke pollution.

3.2 Green area

The total green area of a plant was calculated on the basis of the area per leaf and the number of leaflets per leaf and the number of leaves per plant.

3.2.1 Number of branches per plant

The number of branches per plant in the selected crops under the coal-smoke pollution and in the control are shown in Table 9. In case of *C.arietinum* the number of branches showed a marginal increase over that of control under coal-smoke pollution in the seedling stage. The increase in number, however, has proved to be non-significant on the basis of statistical analysis. In the subsequent stages of growth, *C.arietinum* recorded a decreas in number of branches compared to control, under the influence of coal-smoke pollution, with the loss being highly significant from 60 days old stage to the harvesting period. The other two species, recorded a non-significant loss in the seedling stage and highly significant loss in the subsequent stages with the exception of 40 days old stage in case of *L.culinaris* in which the loss was significant only at 5 per cent level.

3.2.2 Number of leaves per plant

The observations recorded regarding the number of leaves per plant indicates that the selected crop plants underwent heavy losses in leaf number from pre-flowering to

Table 9: Data on the number of branches per plant at different intervals in the selected species at the polluted and control sites

		Days after sowing				
Species	Site	20	40	60	80	100
C. arietinum	P	1.5±0.3	2.0±0.4	3.0±0.3	4.0±0.8	4.5±1.0
	C	1.3±0.2	2.5±0.5	4.0±0.5	6.0±0.9	7.0±0.9
	P.V.	+(15)N.S.	-(20)*	-(25)**	-(33)**	-(38)**
L. culinaris	P	2.0±0.6	2.5±0.6	3.5±1.2	3.9±1.2	4.0±1.3
	C	2.3±0.5	3.2±0.5	5.5±1.4	6.0±1.5	6.0±1.2
	P.V.	-(13)N.S.	-(22)*	-(36)**	-(35)**	-(33)**
P.sativum	P	2.2±0.5	2.5±0.3	3.0±0.8	3.5±0.8	3.8±0.8
	C	2.5±0.4	3.5±0.8	5.0±1.0	6.0±1.2	6.2±1.3
	P.V.	-(12)N.S.	-(29)**	-(40)**	-(42)**	-(39)**

Value are means ± standard deviation
* Significant at $p < 0.05$ level.
** Significant at $p < 0.01$ level.
N.S. Non significant.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

the final stage (Table 10). In case of *P.sativum* the loss in leaf number was found to be significant even at the seedling stage, while in case of *L.culinaris* and *C.arietinum* the seedlings recorded a significant increase and a non-significant increase in leaf number respectively.

Among the three crop plants studied, *P. sativum* faced the severest loss in leaf number amounting up to 55 per cent at the final stage of growth, while *L.culinaris* has shown the least number of leaf loss with the maximum (22 per cent) occurring at 60 days old stage. *C.arietinum* stood in between *P.sativum* and, *L.culinaris*, in having a maximum of 35 per cent loss in leaf number at the harvesting stage.

3.2.3 Number of leaf-lets per leaf

The observations recorded on the number of leaf-lets per leaf are summarized in Table 11. The data indicates that the leaf-let number decreased per leaf at all stages of growth in all the species, the decrease being the highest (31 per cent) in case of *P.sativum*, and it was 27 per cent in *C.arietinum*, and 29 per cent in case of *L.culinaris*.

3.2.4 Leaflet area

The area of leaflets was recorded with the help of a planimeter on graph papers, using 20 replicates in each case. The data collected were analysed and are given in Table 12.

The leaflet area in *C.arietinum* was marginally affected

Table 10: Data showing number of leaves per plant at different intervals in the selected species at polluted and control sites

Species	Site	Days after sowing 20	40	60	80	100
C. arietinum	P	16±1.2	30±5.7	46±6.5	69±8.5	68±12.0
	C	15±1.5	35±3.8	58±8.8	90±9.6	105±10.0
	P.V.	+(7)N.S.	-(14)*	-(21)**	-(23)**	-(35)**
L. culinaris	P	20±1.8	54±8.6	76±9.8	94±9.2	80±8.5
	C	18±1.5	67±7.5	97±7.7	119±8.5	100±9.8
	P.V.	+(11)*	-(19)**	-(22)**	-(21)**	-(20)*
P. sativum	P	7±0.9	10±2.7	22±4.6	32±8.9	20±7.2
	C	8±0.7	16±2.6	38±5.9	58±9.7	45±6.5
	P.V.	-(13)*	-(38)**	-(42)**	-(45)**	-(55)**

Value are means ± standard deviation
* Significant at $p < 0.05$ level.
** Significant at $p < 0.01$ level.
N.S. Non significant.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

at the seedling stage, showing a 4 per cent variation which was statistically non significant. With the growing age of the crop, the leaflet area gets affected to a significant level but on the positive side creating a variation of 7 to 9 per cent at 40 and 60 days old plants and later the variation raised to 14 per cent. It is proved to be highly significant over the control. On the other two species also coal smoke pollution promoted leaflet size to significant level compared to control. In *L.culinaris* the increase in leaflet size was found to be significant till 60 days and later it became only marginal and non significant. In *P.sativum* the increase in leaflet size was significant throughout. The increase was highly significant in this species from second stage of growth to the harvest stage.

3.2.5 Leaf area

The leaf area calculated on individual basis using twenty replicates selected on random basis, out of the 10 replicate plants used in the experiment. The data given in Table 13, thus represents on an average of 200 leaves per species. It is clear from the data given in Table 13 that the average area per leaf was affected under the pollution stress in all the species to varying degrees depending on its nature. In case of *C.arietinum*, there was a non-significant increase in the leaf area in seedlings, while there was a significant decrease in the other stages of growth under the coal-smoke pollution. In case of

Table 11: Data showing the number of leaflets per leaf at different intervals in the selected species at polluted and control sites.

Species	Site	Days after sowing				
		20	40	60	80	100
C. arietinum	P	8±1.3	9±1.5	11±2.5	12±2.5	13±2.3
	C	9±0.8	11±1.4	15±2.6	16±3.2	17±3.0
	P.V.	-(11)N.S.	-(18)*	-(27)**	-(25)**	-(23)**
L. culinaris	P	8±1.5	10±2.1	11±2.1	12±2.5	12±2.4
	C	10±1.9	14±2.5	15±2.4	16±2.8	15±2.6
	P.V.	-(20)*	-(29)**	-(27)**	-(25)**	-(20)*
P. sativum	P	1.0±1.5	1.8±0.28	3.0±0.46	4.4±0.58	4.0±0.50
	C	1.2±0.18	2.2±0.29	4.0±0.58	6.2±0.87	5.8±0.75
	P.V.	-(16)*	-(18)*	-(25)**	-(29)**	-(31)**

Value are means ± standard deviation
*   Significant at $p < 0.05$ level.
**   Significant at $p < 0.01$ level.
N.S. Non significant.
P = Polluted site,   C = Control site,
P.V. = Per cent variation,   G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

Table 12: **Data showing the area of leaflet (in cm^2) at different intervals in the selected species at the polluted and control sites.**

Species	Site	Days after sowing 20	40	60	80	100
C. arietinum	P	0.276±0.10	0.384±0.03	0.530±0.04	0.593±0.05	0.598±0.05
	C	0.287±0.03	0.360±0.02	0.486±0.05	0.520±0.03	0.525±0.06
	P.V.	-(4)N.S.	+(7)*	+(9)*	+(14)**	+(14)**
L. culinaris	P	0.278±0.03	0.321±0.02	0.605±0.05	0.625±0.05	0.630±0.04
	C	0.258±0.02	0.299±0.02	0.564±0.03	0.599±0.06	0.605±0.06
	P.V.	+(9)*	+(7)*	+(7)*	+(4)N.S.	+(4)N.S.
P. sativum	P	4.000±0.13	7.250±0.50	19.720±2.00	22.800±2.00	24.000±2.10
	C	3.800±0.15	6.460±0.60	16.920±2.50	19.190±3.00	20.900±1.80
	P.V.	+(9)*	+(12)**	+(17)**	+(19)**	+(15)**

Value are means ± standard deviation .
* Significant at $p < 0.05$ level.
** Significant at $p < 0.01$ level.
N.S. Non significant.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

P.sativum, there was a consistent increase in the individual leaf area under the pollution stress, from seedling to final stage, the variation being highly significant from flowering to harvest stage but in case of *L.culinaris* the decrease in leaf size occurred to highly significant level from 40-80 days old stage and then it become significant at 5 per cent level.

3.2.6 Total green area per plant

The total green area per plant was calculated on the basis of average leaf area multiplied by total number of leaves in plant using ten plants as replicates for each stage and for each species. The data obtained in this regard are summarized in Table 14. A glance at the data clearly shows that the total green area per plant suffered a heavy loss under coal-smoke pollution. However, the seedling stage in all the three crops did not get affected due to pollution, as the loss or gain in green area was found not significant on statistical analysis. Among the three crops studied, *P.sativum* showed the highest percentage of loss (56 per cent) and it was closely followed by *C.arietinum* (51 per cent) while *L.culinaris* had undergone a maximum loss of only 37 per cent at 40 days old stage.

3.3 BIOMASS

3.3.1 Shoot Biomass

The biomass estimation at different stages of growth

Table 13: Data showing the leaf area (in cm^2) at different stages of growth in the selected species at the polluted and control sites

Species	Site	Days after sowing 20	40	60	80	100
C. arietinum	P	2.880±0.25	3.450±0.25	5.850±0.77	7.110±0.99	7.770±0.75
	C	2.580±0.45	3.960±0.55	7.290±0.89	8.320±0.85	8.920±0.98
	P.V.	-(11)N.S.	-(13)*	-(20)**	-(15)*	-(14)*
L. culinaris	P	2.220±0.25	3.210±0.49	6.650±0.79	7.860±0.95	7.160±1.24
	C	2.580±0.36	4.180±0.65	8.460±0.88	8.550±0.88	8.670±1.50
	P.V.	-(14)*	-(23)**	-(21)**	-(20)**	-(17)*
P. sativum	P	8.000±1.20	16.000±1.80	36.000±3.60	44.000±5.60	48.000±6.20
	C	7.000±0.90	14.000±1.50	32.000±2.50	38.000±4.50	42.000±5.40
	P.V.	+(13)*	+(14)*	+(13)**	+(16)**	+(14)**

Value are means ± standard deviation
* Significant at $p < 0.05$ level.
** Significant at $p < 0.01$ level.
N.S. Non significant.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

Table 14: Data showing the total green area/plant (cm^2) at different intervals in the selected species at the Polluted and control sites

Species	Site	Days after sowing				
		20	40	60	80	100
C. arietinum	P	35±3.1	115±25	292±28	491±29	430±41
	C	38±3.5	161±30	495±39	748±37	882±52
	P.V.	-(8)N.S.	-(29)**	-(41)**	-(34)**	-(51)**
L. culinaris	P	42±3.9	107±31	485±25	666±31	680±51
	C	42±2.9	170±25	681±28	944±43	974±65
	P.V.	+(5)N.S.	-(37)**	-(29)**	-(29)**	-(30)**
P. sativum	P	50±8	145±19	702±45	729±55	650±47
	C	56±9	330±26	1240±37	1212±43	888±54
	P.V.	-(11)N.S.	-(56)**	-(43)**	-(40)**	-(27)**

Value are means ± standard deviation
** Significant at $p < 0.01$ level.
N.S. Non significant.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

has revealed that all the three crops faced significant loss at all stages of growth except the seedling stage in which there was a marginal gain in shoot biomass which on analysis has however proved to be non-significant in Table 15.

3.3.2 Root Biomass

Unlike the shoot biomass, the root biomass suffered heavy losses at all stages of growth including that of the seedling stage. *C.arietinum* suffered to a highly significant level at all stages, *P.sativum* from the second stage of growth, while *L.culinaris* from the third stage i.e. from the flowering stage (Table 16).

3.3.3 Phytomass

The phytomass estimation based on dry weight of the plant revealed that all the three crops undergo significant loss at all stages except the seedling stage in which the estimated loss has been proved to be statistically non-significant. Among the three crops studied, the maximum loss has been come across in *P.sativum* (50 per cent), followed by *L.culinaris* (42 per cent) and *C.arietinum* (38 per cent) all occurring at the 60 days old stage in (Table 17).

3.3.4 Net Primary Productivity

The net primary productivity (NPP) calculated on the

Table 15: Data showing the shoot biomass (in grams) at different intervals in the selected species at the polluted and control sites

Species	Site	Days after sowing				
		20	40	60	80	100
C. arietinum	P	0.200±0.03	0.270±0.04	0.595±0.08	1.950±0.30	2.885±0.60
	C	0.185±0.30	0.325±0.05	0.821±0.06	2.550±0.40	3.880±0.50
	P.V.	+(8)N.S.	-(17)*	-(27)**	-(24)**	-(26)**
L. culinaris	P	0.145±0.03	0.298±0.07	0.622±0.20	1.426±0.20	2.266±0.30
	C	0.130±0.02	0.376±0.05	0.993±0.30	1.998±0.30	2.885±0.50
	P.V.	+(12)N.S.	-(21)*	-(37)**	-(29)**	-(21)*
P. sativum	P	0.300±0.02	0.980±0.15	1.861±0.20	2.889±0.50	2.914±0.90
	C	0.271±0.04	1.291±0.20	2.398±0.30	3.995±0.70	4.561±0.80
	P.V.	+(11)N.S.	-(24)**	-(22)**	-(28)**	-(36)**

Value are means ± standard deviation
* Significant at $p < 0.05$ level.
** Significant at $p < 0.01$ level.
N.S. Non significant.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

Table 16: Data showing the root biomass (in grams) at different intervals in the selec'ed species at the polluted and control sites

Specis	Site	Days after sowing				
		20	40	60	80	100
C. arietinum	P	0.070±0.10	0.090±0.03	0.167±0.50	0.525±0.20	0.595±0.12
	C	0.100±0.02	0.158±0.04	0.340±0.06	1.000±0.40	0.994±0.15
	P.V.	-(30)**	-(43)**	-(51)**	-(48)**	-(40)**
L. culinaris	P	0.065±0.01	0.080±0.02	0.125±0.09	0.356±0.07	0.366±0.12
	C	0.850±0.02	0.104±0.03	0.290±0.05	0.665±0.06	0.675±0.14
	P.V.	-(24)*	-(23)*	-(57)**	-(46)**	-(46)**
P. sativum	P	0.158±0.04	0.180±0.06	0.564±0.10	1.050±0.40	1.190±0.24
	C	0.200±0.40	0.316±0.08	1.020±0.12	2.000±0.80	1.988±0.30
	P.V.	-(21)*	-(43)**	-(45)**	-(48)**	-(40)**

Value are means ± standard deviation
* Significant at $p < 0.05$ level.
** Significant at $p < 0.01$ level.
N.S. Non significant.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

Table 17: Data showing the phytomass(in grams) at different intervals in the selected species at polluted and control sites

Species	Site	Days after sowing				
		20	40	60	80	100
C. arietinum	P	0.279±0.02	0.460±0.08	0.962±0.52	2.470±0.76	4.470±0.90
	C	0.285±0.03	0.583±0.09	1.520±0.64	3.550±0.84	6.100±0.82
	P.V.	-(2)N.S.	-(21)*	-(38)**	-(30)**	-(28)**
L. culinaris	P	0.210±0.03	0.378±0.08	0.997±0.30	1.982±0.44	2.632±0.41
	C	0.215±0.04	0.480±0.09	1.283±0.52	2.661±0.63	3.560±0.70
	P.V.	-(2)N.S.	-(21)*	-(42)**	-(26)**	-(26)*
P. sativum	P	0.439±0.02	1.160±0.22	2.695±0.85	3.539±0.85	4.104±0.87
	C	0.471±0.03	1.607±0.34	3.418±0.77	4.995±0.98	5.949±0.89
	P.V.	-(7)N.S.	-(28)**	-(50)**	-(34)**	-(37)**

Value are means ± standard deviation
* Significant at $p < 0.05$ level.
** Significant at $p < 0.01$ level.
N.S. Non significant.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

basis of phytomass obtained at the different stages of growth showed that all the three crops studied faced a deep fall in their productivity due to coal-smoke pollution to the extent of high significance at all stages of growth except the first stage in which the calculated loss was only marginal and not significant in statistical sense. The different crops had shown the maximum loss of NPP at different stages of growth. *C.arietinum* suffered the highest loss of 44 per cent at 40 days old stage and *L.culinaris* faced the maximum loss of 28 per cent at 60 days old stage , while *P. sativum* recorded a maximum loss of 46 per cent at 80 days old stage (Table 18).

3.4 REPRODUCTIVE GROWTH ACTIVITY

Reproductive growth activity was studied at an interval of 20 days starting from 60 days upto the harvest period. The data collected in this connection are summarized in Table 19. The reproductive growth was significantly affected in all the three crops to the extent of 2[illegible] per cent in *C.arietinum* and 27 per cent in *L.culinaris* and 23 per cent in *P.sativum*.

The number of fruits set in each plant was recorded and the data are presented in Table 19. Like flowering, the fruit-set has also been observed to gets affected to a highly significant level in all the three crops. The maximum loss was recorded in *C.arietinum* (27 per cent) followed by *P.sativum* (25 per cent) and *L.culinaris* (20

Table 18: Data showing the Net primary productivity at different intervals in selected species at the polluted and control sites.

Species	Site	Days after sowing				
		20	40	60	80	100
C. arietinum	P	0.013±0.001	0.034±0.013	0.075±0.015	0.059-0.014	0.040±0.0
	C	0.014±0.002	0.061±0.015	0.101±0.018	0.078±0.016	0.049±0.0
	P.V.	-(7)N.S.	-(44)**	-(26)**	-(26)**	-(18)*
L. culinaris	P	0.010±0.001	0.039±0.001	0.049±0.012	0.032±0.001	0.023±0.0
	C	0.011±0.001	0.053±0.011	0.068±0.013	0.044±0.011	0.029±0.0
	P.V.	-(9)N.S	-(26)**	-(28)**	-(27)**	-(21)**
P. sativum	P	0.021±0.005	0.036±0.011	0.050±0.022	0.042±0.021	0.028±0.0
	C	0.023±0.006	0.056±0.012	0.090±0.025	0.078±0.026	0.047±0.0
	P.V.	-(9)N.S.	-(36)**	-(44)**	-(46)**	-(40)**

Value are means ± standard deviation
* Significant at $p < 0.05$ level.
** Significant at $p < 0.01$ level.
N.S. Non significant.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

per cent).

At the harvest period, the number of seeds per pod was recorded and found that it was heavily affected by coal smoke pollution in all the three crops. Since the flowering as well as the fruit-setting and the number of seed per fruit were affected highly, the yield per plant also gets highly affected in all the three crops. *C.arietirum* was found to lose 34 per cent of its yield due to coal-smoke pollution, *P.sativum* 32 per cent and *L.culinaris* 24 per cent . Not only the yield was affected, the seed vigour and weight, also gets affected under pollution. The highest loss in seed weight, was observed in *L.culinaris* (33 per cent) following by *P.sativum* 31 per cent and *C.arietinum* 14 per cent under coal-smoke pollution.

On the basis of data collected the harvest index was calculated for all the three crops and found to be affected to highly significant level in all. The highest loss in the index was noted in case of *P.sativum* (28 per cent), followed by *C.arietinum* 22 per cent and *L.culinaris* 21 per cent.

3.4.1 Seed viability

In the following sowing season i.e. in October November, the seeds were tested for their viability, using tetrazolium salt, (2,3,5 Triphenyl tetrazolium chloride) at one per cent concentration following the method described by

Table 19: Data showing the reproductive growth activity (Number of flowers, Number of fruits, Number of Seed per pod, Number of Seed per plant, Seed weight per plant and harvest index) in the selected species at polluted and control sites.

Species	Site	No.Flower per plant	No.of fruits per plant	No.of seed per pod.	No.of seed per plant	Hundred seed weight per plant	Harvest index
C. arietinum	P	15±2.7	11±2	1.7±.15	19.8±05	28.18±1.5	126.43±12.0
	C	20±3.3	15±2.5	2.0±.20	30.0±08	32.88±1.9	161.40±15.0
	P.V	-(25)**	-(27)**	-(15)**	-(34)**	-(14)**	-(22)**
L. culinaris	P	48±8.7	35±5	1.7±.25	63±10	1.72±.5	41.00±00.8
	C	66±7.5	44±4	1.9±.15	83±12	2.55±.7	52.00±00.9
	P.V	-(27)**	-(20)**	-(11)**	-(24)**	-(33)**	-(21)**
P. sativum	P	10±1.4	9±1.5	4.5±.75	45±9	15.54±2.5	170.12±21.0
	C	13±2.2	12±2	5.5±.92	66±14	22.64±3	237.49±25.0
	P.V	-(23)**	-(25)**	-(18)**	-(32)**	-(31)**	-(28)**

Value are means ± standard deviation
** Significant at $p < 0.01$ level.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

Kuhn and Jerchel (1941). It was found that the viability of seeds in all the three crops was affected to a highly significant level in plants which faced coal-smoke pollution (Table 20).

3.4.2 Seed Germination

When the seeds were germinated in petri plates at 30°C, it was found that the seed germination in all the three crops was affected to a highly significant level (Table 20). The germination in *P.sativum* was affected to a maximum level of 35 per cent and in case of *C.arietinum* 22 per cent and in *L.culinaris* 17 per cent.

3.4.3 Reproductive Capacity (R.C.)

The reproductive capacity was calculated using the formula given by Ambasht (1986).

$$R.C. = \frac{\text{Seed out put} \times \text{Number of seed germinated}}{100}$$

The data obtained in the present study, regarding the reproductive capacity of the crops investigated are given in Table 20, together with the per cent variation and their significance. A glance of the data given in Table 20 clearly indicates that all the three crops suffered to a highly significant level in their reproductive capacity, *P.sativum* being the worst affected. The reproductive capacity of this species was reduced to 57 per cent, by coal smoke pollution compared to control. *C.arietinum* lost 49 per

Table 20 Shows the data on seed viability, seed germination and reproductive capacity of the selected species at polluted and control sites.

Species	Site	Seed Viability	Seed germination	Reproductive capacity
C. arietinum	P	86.0±11.40	58.8±6.58	11.64±5
	C	97.0±02.50	75.5±7.90	22.65±8
	P.V.	-(11)**	-(22)**	-(49)**
L. culinaris	P	87.0±8.4	78.0±3.1	49.14±10
	C	98.0±1.14	94.0±5.7	78.02±12
	P.V.	-(11)**	-(17)**	-(37)**
P. sativum	P	79.6±5.02	55.0±7.9	24.75±9
	C	94.0±2.34	85.0±11.9	56.10±14
	P.V.	-(15)**	-(35)**	-(57)**

Value are means ± standard deviation
** Significant at $p < 0.01$ level.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

cent of its reproductive capacity, while *L.culinaris* was affected by 37 per cent in its reproductive capacity under coal-smoke pollution.

3.5 BIOCHEMICAL ANALYSIS

In order to learn about the changes at cellular level, certain biochemical aspects such as analysis of coloured pigments, protein , N.P.K. levels and cellular sulphur have been under taken and the results with analysis are summarized in Table 21-41.

3.5.1 Pigment Analysis

Table 21 shows the data on chlorophyll 'a' contents in the green leaves of the selected species at the normal and polluted site. It becomes clear from the data that chlorophyll 'a' was affected to a highly significant level in all the three crops at all stages of growth. In *C.arietinum* the maximum loss of 25 per cent was recorded due to coal smoke pollution at 80 days old stage while in *L.culinaris* a maximum of 23 per cent was recorded at the seedling stage indicating the high vulnerability of this species to coal smoke pollution at this growth stage. In case of *P.sativum* the highest variation caused by coal smoke pollution occurred at 40 days old stage.

Table 22 shows the results on the loss or gain of chlorophyll 'a' in green leaves in the selected species at the normal and polluted sites at different stages of

Table 21: Data on the chlorophyll "a" contents (mg/g fresh weight) in polluted and control samples of the selected species at different intervals

Species	Site	Days after sowing					
		20	40	60	80	[illegible]	average
C. arietinum	P	1.350±0.05	2.340±0.08	2.770±0.09	2.200±0.09	1.9[illegible]±0.08	2.112
	C	1.450±0.09	2.660±0.06	3.280±0.11	2.950±0.13	2.25[illegible]±0.11	2.518
	P.V.	-(7)**	-(12)**	-(16)**	-(25)**	-[illegible]**	(15.2
L. culinaris	P	0.766±0.13	1.450±0.19	1.885±0.15	1.810±0.21	0.885±0.12	1.359
	C	0.996±0.12	1.720±0.12	2.380±0.17	2.116±0.13	[illegible]±0.15	1.664
	P.V.	-(23)**	-(16)**	-(21)**	-(14)**	-[illegible]**	(18.8
P. sativum	P	0.624±0.04	0.676±0.12	1.330±0.12	0.876±0.03	[illegible]±0.09	0.836
	C	0.698±0.06	0.869±0.13	1.667±0.15	0.991±0.05	[illegible]±0.07	1.007
	P.V.	-(11)**	-(22)**	-(20**	-(12)**	-[illegible]**	(14.4)

Value are means ± standard deviation
** Significant at $p < 0.01$ level.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

growth. A comparison of the given data shows that all the three species behaved in a similar trend. In all the daily rate of formation of chlorophyll 'a' was higher in the first 20 days than in the other growth stages. Its daily rate decreased either gradually or otherwise up to 60 days old stage. In case of *C.arietinum* and *L.culinaris* the daily rate of formation declined gradually to strike the minimum at 60 days old stage while in case of *P.sativum* the decline was deep at 40 days old stage both in the control as well as in the polluted population indicating the inherent behaviour of the species. After the 60 days old stage, the degeneration process started, in chlorophyll 'a' in all the species. The process of degeneration was accelerated under the influence of coal smoke pollution and caused wide per cent variation in the affected population compared to control. The maximum variation occurred at 80 days old stage amounting upto 73 per cent, 77 per cent and 33 per cent in Gram, Lentil and Pea respectively.

Table 23 shows the data on chlorophyll 'b' content in the green leaves of the selected species at different stages of growth at the normal and polluted sites. glance at the data makes it clear that all the three crops suffered highly in chlorophyll 'b' content under the influence of coal smoke pollution. Compared to the other two species, *L. culinaris* appeared to be some what

Table 22: Data showing the rate of gain/loss of chloroplyll "a" content in polluted and control samples of selected species at different intervals

Species	Site	Days after sowing				
		20	40	60	80	100
C. arietinum	P	0.0675	0.0495	0.0215	-0.285	-0.015
	C	0.0725	0.0605	0.0310	-0.165	-0.035
	P.V.	-(7)	-(18)	-(47)	-(73)	-(57)
L. culinaris	P	0.0383	0.0342	0.0217	-0.003	-0.046
	C	0.0498	0.0362	0.0330	-0.013	-0.056
	P.V.	-(23)	-(6)	-(34)	-(77)	-(18)
P. sativum	P	0.0312	0.102	0.0327	-0.277	-0.0089
	C	0.0349	0.208	0.0399	-0.338	-0.0099
	P.V.	-(11)	-(75)	-(51)	-(33)	-(11)

P = Polluted site, C = Control site,
P.V. = Percent variation,
(+) / (-) indicate per cent increase or decrease over control.

stable against coal smoke pollution as the loss of chlorophyll 'b' was non significant at 20 days old stage. The Table 24 shows the picture of daily rate of formation or degeneration of chlorophyll 'b' both in the normal and polluted site. In all the three crops, the formation decreased from 20 to 60 days and later degeneration started under normal as well as in the polluted site. In case of *C.arietinum* and *P.sativum* the formation rate falls gradually while in *L. culinaris* the fall was deep at 40 days old stage, followed by a moderate recovery in the next 20 days.

In *P. sativum* at 40 day old stage the formation of chlorophyll 'b' started heavily even at the normal conditions indicating inherent character. In *L.culinaris* the fall at 40 days was not so sharp as in *P.sativum*.

After 60 days old stage, the degeneration of chlorophyll 'b' started in all the three crops as in case of chloropyll 'a' under coal smoke pollution. The degeneration rate gets aggravated in all the three crops, *C.arietinum* recording the widest variation of 33 per cent followed by *P.sativum* (25 per cent at 80 days old stage). In case of *L.culinaris* the degeneration of chlorophyll 'b' due to coal smoke was only marginal (4 per cent) compared to the normal (Table 24).

Calculated values shows the data on total chlorophyll contents of green leaves in the selected crops at

Table 23: Data on the Chlorophyll 'b' content (mg/g fresh weight) in polluted and control dsamples of the selected species at different intervals

Species	Site	Days after sowing					
		20	40	60	80	100	average
C. arietinum	P	0.515±0.03	0.875±0.05	1.121±0.06	1.000±0.04	0.760±0.06	0.854
	C	0.665±0.05	0.985±0.09	1.292±0.08	1.110±0.05	0.860±0.03	0.962
	P.V.	-(9)*	-(11)**	-(13)**	-(10)**	-(12)**	11.0
L. culinaris	P	0.580±0.09	0.912±0.08	1.350±0.13	0.998±0.06	0.691±0.06	0.90[illegible]
	C	0.605±0.15	0.998±0.07	1.480±0.14	1.112±0.07	0.747±0.04	0.98[illegible]
	P.V.	-(4)N.S	-(9)*	-(9)*	-(10)**	-(7)*	7.8
P. sativum	P	0.551±0.04	0.655±0.05	0.965±0.05	0.844±0.09	0.645±0.04	0.73[illegible]
	C	0.5[illegible]±0.03	0.722±0.07	1.133±0.11	0.965±0.06	0.725±0.06	0.827
	P.V.	[illegible]*	-(9)*	-(15)**	-([illegible])**	-(11)**	11.0

Value are means ± standard deviation
* Significant at $p < 0.05$ level.
** Significant at $p < 0.01$ level.
N.S. Non significant.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

Table 24: Data showing the rate of gain/loss of chlorophyll "b" in polluted and control samples of selected species at different intervals

Species	Site	Days after sowing				
		20	40	60	80	100
C. arietinum	P	0.0257	0.0180	0.0123	-0.0060	-0.0120
	C	0.0282	0.0210	0.0153	-0.0090	-0.0125
	P.V.	-(9)	-(14)	-(20)	-(33)	-(4)
L. culinaris	P	0.0290	0.0166	0.0219	-0.0152	-0.0176
	C	0.0320	0.0196	0.0241	-0.0182	-0.0184
	P.V.	-(9)	-(15)	-(9)	-(16)	-(4)
P. sativum	P	0.0275	0.0050	0.0155	-0.0060	-0.0090
	C	0.0295	0.0060	0.0205	-0.0080	-0.0120
	P.V.	-(7)	-(17)	-(24)	-(25)	-(25)

P = Polluted site, C = Control site,
P.V. = Percent variation,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

different stages of growth in normal and polluted sites are presented in Table 25. A glance at the data indicates that all the three crops suffered heavily in chlorophyll content under the influence of coal smoke pollution. The loss in total chlorophyll content was highly significant in all the three crops including at the first stage in case of *L.culinaris*. The formation or degeneration of total chlorophyll in the selected crops is summarized in Table 26. The data clearly indicates that the formation of chlorophylls occurred only up to 60 days and there after degeneration started. The daily rate of formation of chloryphylls falls gradually in *C.arietinum* and in *P.sativum*, while *L. culinaris* took a deep fall at 40 days old stage and then slightly improved subsequently. The trend of formation and degeneration was maintained even under coal-smoke pollution.

The (Table 27) shows the ratio of total chlorophyll in normal and polluted population of selected species. In *C.arietinum* and *L.culinaris* the ratio was quite high (1:0.860 and 1:0.862) while in *P.sativum* it was quite low (1:0.245) under the pollution stress, indicating the high sensitvity of chlorophylls of this species to coal-smoke.

Table 28 shows the strategy of carotenoids in the green leaves of the selected crops under the normal and polluted sites. The data indicate that the carotenoids suffered a significant loss in all the three crops due to coal smoke pollution. The loss, due to coal smoke pollution was non-significant at the seedling stage but highly significant at 40 days old stage in all the three crops. The loss continued to be highly significant at 60 days old stage in *C.arietinum* and *P.sativum* while *L.culinaris* appeared to be some what tolerant in this regard.

Table 29 shows the daily rate of formation of carotenoid in the selected species at the normal and polluted sites. Unlike the chlorophylls, carotenoids continued to form till the last stage in control. It also becomes clear from the data that the daily rate of formation of carotenoids gets affected due to coal smoke pollution to the maximum of 37 per cent in *C.arietinum*, 23 per cent in *L. culinaris* and 66 per cent in *P.sativum*.

Table 30 shows the ratio of chlorophyll 'a' and chlorophyll 'b' in the selected species, and the disturbance caused by coal smoke pollution. It is clear from the data that the species investigated have their own ratio of chlorophyll 'a' and 'b' under normal conditions, which in average comes to 1:0.382, 1:0.598 and 1:0.840 in *C.arietinum*, *L.culinaris* and *P.sativum* respectively. In all the three cases, the ratio of chlorophyll 'b' became high under coal smoke pollution. This may be due to the higher sensitivity of chlorophyll 'a' to coal smoke than chlorophyll 'b'. In other words chlorophyll 'a' is more vulnerable to coal smoke pollution than chlorophyll 'b'.

Table 28: Data on carotenoids contents (mg/g fresh weight) in polluted and control samples of the selected species at different intervals

Species	Site	Days after sowing 20	40	60	80	100
C. arietinum	P	0.410±0.05	0.621±0.03	0.712±0.05	0.891±0.05	0.930±0.08
	C	0.424±0.03	0.682±0.05	0.795±0.03	0.960±0.07	1.020±0.09
	P.V.	-(2)N.S.	-(9)**	-(10)**	-(7)*	-(8)*
L. culinaris	P	0.361±0.07	0.545±0.03	0.701±0.03	0.844±0.02	0.865±0.05
	C	0.371±0.08	0.603±0.02	0.755±0.06	0.888±0.05	0.915±0.03
	P.V.	-(3)N.S	-(10)**	-(7)*	-(5)*	-(5)*
P. sativum	P	0.396±0.02	0.625±0.04	0.718±0.05	0.773±0.04	0.791±0.02
	C	0.393±0.02	0.704±0.05	0.787±0.03	0.812±0.03	0.825±0.04
	P.V.	+(6)N.S.	-(11)**	-(9)**	-(5)*	-(4)*

Value are means ± standard deviation
* Significant at $p < 0.05$ level.
** Significant at $p < 0.01$ level.
N.S. Non significant.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease ove control.

Table 29: Data showing the rate of gain or loss of carotenoids in polluted and control samples of the selected species at different intervals

		Days after sowing				
Species	Site	20	40	60	80	100
C. arietinum	P	0.0208	0.0102	0.0045	0.0089	0.001[illegible]
	C	0.0212	0.0129	0.0056	0.0082	0.0030
	P.V.	-(2)	-(21)	-(20)	+(9)	-(37)
L. culinaris	P	0.0180	0.0092	0.0078	0.0071	0.0010
	C	0.0185	0.0116	0.0076	0.0066	0.0013
	P.V.	-(3)	-(21)	+(3)	+(8)	-(23)
P. sativum	P	0.0184	0.0128	0.0046	0.0020	0.0006
	C	0.0196	0.0155	0.0041	0.0060	0.0009
	P.V.	-(8)	-(17)	+(12)	-(66)	-(50)

P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

Table 30: Data showing the rate of photosynthetic pigments chl. a:b in polluted and control samples of selected species at different intervals

Species	Site	Days after sowing					
		20	40	60	80	100	average
C. arietinum	P	1:0.381	1:0.372	1:0.404	1:0.454	1:0.400	1:0.402
	C	1:0.389	1:0.370	1:0.393	1:0.376	1:0.382	1:0.382
L. culinaris	P	1:0.757	1:0.628	1:0.710	1:0.550	1:0.780	1:0.685
	C	1:0.600	1:0.580	1:0.620	1:0.520	1:0.670	1:0.598
P. sativum	P	1:0.880	1:0.960	1:0.720	1:0.960	1:0.950	1:0.894
	C	1:0.840	1:0.830	1:0.670	1:0.970	1:0.890	1:0.840

P = Polluted site, C = Control site,

The persent variations caused by coal smoke pollution on chlorophyll 'a' and 'b' made it clear that in *C.arietinum* chlorophyll 'a' was affected 15.2 per cent while 'b' suffered only 11 per cent in average (Table 21 & 23). In case of *L.culinaris* the P.V. was 18.8 for 'a' against 7.8 of chlorophyll 'b'. In *P. sativum* 14.4 per cent for chlorophyll 'a' against 11.00 of chlorophyll 'b'(Table 21). A comparison of the above makes it clear that the high rate of death and degeneration of chlorophyll 'a' naturally leads to the higher percentage of chlorophyll 'b' in the cells under coal smoke pollution than in control.

The ratio of total chlorophyll content and the carotenoids in the green leaves of the selected species, under normal and polluted conditions are shown in Table 31. The relative content of carotenoids in comparison to chlorophylls recorded a higher amount under coal smoke pollution compared to normal. This again was due to higher vulnerability of chlorophylls than carotenoids to coal-smoke pollution.

3.5.2 Protein

The variation in protein content has been analysed in the selected species at the different stages of growth both in the control and in the polluted population, following the method given by Lowry *et al.* (1951). It was noted that under the coal-smoke pollution, the protein contents are in general, found to be severely affected.

Table 31: Data showing the ratio of total chlorophyll and carotenoids in polluted and control samples of the selected species at different intervals

Species	Site	Days after sowing 20	40	60	80	100	average
C. arietinum	P	1:0.223	1:0.193	1:0.182	1:0.278	1:0.349	1:0.245
	C	1:0.210	1:0.187	1:0.173	1:0.236	1:0.327	1:0.226
L. culinaris	P	1:0.268	1:0.230	1:0.216	1:0.300	1:0.548	1:0.312
	C	1:0.231	1:0.221	1:0.195	1:0.275	1:0.528	1:0.290
P. sativum	P	1:0.314	1:0.469	1:0.312	1:0.449	1:0.598	1:0.428
	C	1:0.304	1:0.442	1:0.281	1:0.415	1:0.536	1:0.395

P = Polluted site, C = Control site,

3.5.2.1 Root Protein

The (Table 32) shows the data obtained on root protein in all the three species investigated. It is clear from the per cent variation between the polluted and control populations that protein contents in the roots decreased to a highly significant level at all stages of growth, indicating that the root system in all the three crops studied was very sensitive to coal smoke pollution, as far as the protein is concerned.

3.5.2.2 Shoot Protein

The data on shoot protein obtained in the present study are revealed in Table 33. Like the root protein, the shoot protein also decreased to a significant level in all the three species at all stages of growth. Percent variation obtained in the shoot protein content between the polluted and control population clearly shows that the depletion in the protein content, due to coal-smoke pollution, was highly significant in *L.culinaris* and *P.sativum* at all stages of growth. However, in *C.arietinum*, the depletion in shoot protein was, although high in the seedling stage, but not later. In this species, from 40 day old stage to the harvest stage, the depletion in shoot protein was only moderate (significant at 5 per cent level).

Table 25: Data showing the total chloroplyll content (mg/g fresh weight) in polluted and control samples of the selected species at different intervals

Species	Site	Days after sowing				
		20	40	60	80	100
C. arietinum	P	1.865±0.12	3.215±0.15	3.891±0.26	3.200±0.19	2.660±0.30
	C	2.015±0.15	3.645±0.35	4.572±0.43	4.060±0.37	3.110±0.25
	P.V.	-(7)*.	-(12)**	-(15)**	-(21)**	-(14)**
L. culinaris	P	1.346±0.15	2.362±0.19	3.235±0.24	2.808±0.21	1.576±0.16
	C	1.601±0.18	2.718±0.26	3.860±0.39	3.228±0.28	1.758±0.18
	P.V.	-(16)**	-(13)**	-(16)**	-(13)**	-(10)*
P. sativum	P	1.175±0.09	1.331±0.15	2.295±0.22	1.720±0.22	1.322±0.13
	C	1.289±0.12	1.591±0.18	2.800±0.32	1.956±0.06	1.537±0.15
	P.V.	-(9)*	-(16)**	-(18)**	-(12)**	-(14)**

Value are means ± standard deviation
*   Significant at $p < 0.05$ level.
**   Significant at $p < 0.01$ level.
P = Polluted site,   C = Control site,
P.V. = Per cent variation,   G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

Table 26: Data showing the rate of total chloroplyll development in polluted and control samples of the selected species at different intervals

Species	Site	Days after sowing				
		20	40	60	80	100
C. arietinum	P	0.0932	0.0675	0.0338	-0.0345	-0.0475
	C	0.1007	0.0815	0.0463	-0.0256	-0.0270
	P.V.	-(7)	-(17)	-(27)	+(33)	+(43)
L. culinaris	P	0.0673	0.0508	0.0436	-0.0316	-0.0735
	C	0.0800	0.0558	0.0571	-0.0213	-0.0616
	P.V.	-(16)	-(9)	-(24)	+(33)	+(16)
P. sativum	P	0.0587	0.0570	0.0482	-0.0422	-0.0209
	C	0.0644	0.0631	0.0604	-0.0287	-0.0199
	P.V.	-(9)	-(10)	-(20)	+(32)	+(5)

P = Polluted site, C = Control site,
P.V. = Percent variation,
(+) / (-) indicate per cent increase or decrease over control.

Table 27: Data showing the ratio of total chlorophyll in polluted and control samples of the selected species at different intervals

		Days after sowing					
Species	Site	20	40	60	80	100	average
C. arietinum	C:P	1:0.925	1:0.882	1:0.851	1:0.788	1:0.855	1:0.860
L. culinaris	C:P	1:0.840	1:0.869	1:0.838	1:0.869	1:0.896	1:0.862
P. sativum	C:P	1:0.223	1:0.193	1:0.182	1:0.278	1:0.349	1:0.245

P = Polluted site,
C = Control site,
C:P = Ratio of total chlorphyll in control and polluted site.

3.5.2.3 Average protein content

On the basis of the observations on protein content in root and shoot systems, the average protein content in the plant, as a whole, was worked out and analysed statistically. The data given in Table 34 shows that the protein content, in general, decreased in the polluted population due to coal-smoke pollution to various levels in the different species. In *C.arietinum*, the drop in the protein content, due to coal-smoke pollution was found to be of high significance from 60 days old to the harvest stage, while in the case of *L.culinaris*, the same happened at 80 and 100 days old stage. In these two species the per cent variation, however, happened to be non-significant at the seedling stage but it was significant at 5 per cent level at 40 and 60 days old stages. In *P.sativum* the average protein content of the plants decreased to a highly significant level at all stages of growth except the first stage in which the decrease in protein content was only moderate and it was found to be significant only at 5 per cent level.

3.5.3 The Sulphate-Sulphur content

The sulphate sulphur content was analysed in root and shoot of the selected species in the control and polluted sites at different intervals following the method described by Patterson (1958).

Table 32: The protein contents of root (Per cent dry weight) in polluted and control samples of the selected species, at different stages of their growth

Species	Site	Days after sowing				
		20	40	60	80	100
C. arietinum	P	11.40±1.50	12.02±1.60	14.25±1.60	12.54±2.30	10.60±0.62
	C	14.53±1.80	15.10±1.40	17.10±1.90	17.20±2.50	11.51±0.63
	P.V.	-(22)**	-(20)**	-(17)**	-(27)**	-(8)**
L. culinaris	P	3.09±0.52	15.00±1.40	17.67±1.70	13.11±0.86	10.14±0.63
	C	08.94±0.64	17.00±1.50	19.95±1.80	14.82±0.98	11.11±0.74
	P.V.	-(9)**	-(12)**	-(11)**	-(12)**	-(9)**
P. sativum	P	13.85±1.60	15.90±1.70	15.10±2.50	12.54±2.30	10.71±0 44
	C	16.13±1.70	18.52±1.90	20.52±2.70	16.53±2.60	11.45±C 64
	P.V.	(14)**	-(19)**	-(26)**	-(24)**	-(6 **

Value are means ± standard deviation

** Significant at $p < 0.01$ level.

N.S. Non significant.

P = Polluted site, C = Control site,

P.V. = Per cent variation, G.I. = Growth index.

(+) / (-) indicate per cent increase or decrease over control.

Table 33: The protein Contents of shoot (per cent dry weight) in polluted and control samples of the selected species, at different stages of their growth

Species	Site	Days after sowing				
		20	40	60	80	100
C. arietinum	P	18.24±0.85	25.65±2.60	29.07±3.50	19.95±4.20	14.25±2.30
	C	19.95±0.97	31.35±2.70	37.00±3.80	28.50±4.90	19.95±2.90
	P.V.	-(9)**	-(18)*	-(21)*	-(30)*	-(29)*
L. culinaris	P	15.96±1.50	19.95±2.90	24.51±3.30	14.25±4.50	11.40±4.80
	C	18.81±1.80	25.65±2.80	30.78±3.90	22.80±5.40	19.95±3.80
	P.V.	-(15)**	-(22)**	-(20)**	-(38)**	-(43)**
P. sativum	P	14.25±1.60	22.81±5.50	29.64±7.60	19.95±5.20	14.25±2.80
	C	16.13±1.70	33.06±6.80	43.32±6.40	28.53±6.40	19.95±2.70
	P.V.	-(17)*	-(31)**	-(32)**	-(30)**	-(29)*

Value are means ± standard deviation
* Significant at $p < 0.05$ level.
** Significant at $p < 0.01$ level.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

Table 34: Average protein content of Shoot and Root (per cent dry weight) in polluted and control samples of the selected species at different stages of their growth

Speceis	Site	Days after sowing				
		20	40	60	80	100
C. arietinum	P	14.82±1.30	18.83±2.00	21.62±1.70	16.24±1.90	12.41±1.10
	C	17.24±1.60	23.22±3.04	27.05±1.19	22.85±2.10	15.73±1.50
	P.V.	-(14)N.S.	-(19)*	-(20)**	-(28)**	-(21)**
L. culinaris	P	12.02±1.60	17.47±1.70	21.09±2.50	13.68±1.80	10.77±1.05
	C	13.87±1.90	21.32±1.90	25.36±3.00	18.81±1.50	14.54±1.20
	P.V.	-(13)N.S.	-(18)*	-(17)*	-(27)**	-(26)**
P. sativum	P	14.05±1.70	19.35±2.10	22.37±2.50	16.24±1.80	12.48±0.98
	C	16.61±1.50	25.79±2.30	31.92±3.60	22.51±2.20	15.70±1.20
	P.V.	-(15)*	-(25)**	-(30)**	-(28)**	-(20)**

Value are means ± standard deviation
* Significant at $p < 0.05$ level.
** Significant at $p < 0.01$ level.
N.S. Non significant.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

3.5.3.1 Sulphate - Sulphur in Roots

The data presented in Table 35 shows the sulphate - sulphur content in the root system of the selected species. The sulphate-sulphur generally increased in the root system of the selected crops to a significant level under the coal-smoke pollution. However, in the first two stages of growth i.e. in the young plants, of *C.arietinum*, sulphate -sulphur content decreased marginally (non-significant) under the coal-smoke pollution. But in the case of *L.culinaris* , there was a marginal increase in the inorganic sulphur content in the first two stages of growth, while in the case of *P.sativum* in the young plants of 20 days old, the sulphur content recorded an increase of 16 per cent over the control, and this increase was not significant in statistical sense. A linear increase in sulphur content in *P.sativum* was noted in the subsequent stages of growth to a level of high significance, yielding the maximum of 60 per cent at the final stage of harvest. In the case of *C.arietinum* also, the maximum sulphur content (58 per cent) was noted at the harvest stage. In case of *L.culinaris* the sulphur content increased to the extent of 43 per cent in 60 days old plnats and later it gradually droped to reach 29 per cent at the harvest stage.

3.5.3.2 Sulphate - Sulphur in Shoot

Unlike in the roots, the sulphate- sulphur in the shoot system of the selected species recorded a uniformly higher amounts of sulphate-sulphur under coal-smoke pollution compared to control at all the stages of growth. The increase in sulphur content due to coal-smoke pollution was highly significant at all stages of growth in all the three species, excepting *C.arietinum* which showed a moderate increase in the sulphur content at the seedling stage (Table 36). The maximum of 65 per cent increase was noted in *P.sativum* in 80 days old plants, while the maximum of 53 per cent has been recorded in 60 and 80 days old plants of *C.arietinum*. In *L.culinaris*, on the other hand, the maximum amount (46 per cent) of sulphur was recorded in 60 days old plants (Table 36).

3.5.3.3 Average Sulphur content

The average sulphur content in the test crops was calculated out of the data obtained from the roots and shoots of the respective crop. The data obtained in this regard given in Table 37 indicate that there was a positive increase in sulphur content in the plant body of the selected species to a significant level in all with the exception of *C.arietinum* in which the increase in sulphur content was non-significant up to 40 days. In the other two species, the increase in sulphur content was significant even in the seedling stage. The highest amount (60 per cent) of sulphur content was obtained for *P.sativum*

Table 35: Data on the sulphate sulphur content (percent dry weight) in Roots of the selected species in control and polluted samples at different intervals.

		Days after sowing				
Speceis	Site	20	40	60	80	100
C. arietinum	P	0.172±0.02	0.176±0.01	0.210±0.04	0.225±0.04	0.198±0.04
	C	0.182±0.01	0.185±0.03	0.160±0.02	0.190±0.03	0.125±0.06
	P.V.	-(5)N.S	-(5)N.S.	+(31)**	+(18)*	+(58)**
L. culinaris	P	0.203±0.025	0.258±0.070	0.300±0.031	0.383±0.35	0.225±0.019
	C	0.185±0.026	0.225±0.049	0.288±0.017	0.2[illegible]8±0.023	0.175±0.023
	P.V.	+(10)N.S.	+(15)N.S.	+(43)**	+(33)**	+(29)**
P. sativum	P	0.220±0.07	0.356±0.05	0.390±0.02	0.307±0.04	0.300±0.09
	C	0.190±0.07	0.266±0.03	0.285±0.03	0.202±0.02	0.188±0.07
	P.V.	+(16)N.S.	+(34)**	+(37)**	+(52)**	+(60)**

Value are means ± standard deviation
*   Significant at $p < 0.05$ level
**   Significant at $p < 0.01$ level.
N.S. Non significant.
P = Polluted site,   C = Control site,
P.V. = Per cent variation,   G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

Table 36: Data on sulphate sulphur content (per cent dry weight) in shoots of of the selected species in control and polluted samples at different intervals

		Days after sowing				
Species	Site	20	40	60	80	100
C. arietinum	P	0.175±0.03	0.265±0.04	0.345±0.05	0.390±0.06	0.290±0.04
	C	0.150±0.02	0.200±0.05	0.225±0.03	0.225±0.05	0.220±0.05
	P.V.	+(17)*	+(33)**	+(53)**	+(53)**	+(32)**
L. culinaris	P	0.211±0.05	0.280±0.04	0.350±0.07	0.377±0.06	0.286±0.05
	C	0.158±0.03	0.215±0.05	0.240±0.08	0.266±0.09	0.224±0.04
	P.V.	+(34)**	+(3[illegible])**	+(46)**	+(42)**	+(28)**
P. sativum	P	0.225±0.04	0.270±0.04	0.380±0.05	0.405±0.08	0.300±0.08
	C	0.168±0.03	0.195±0.05	0.235±0.08	0.245±0.09	0.212±0.05
	P.V.	+(34)**	+(38)**	+(62)**	+(65)**	+(42)**

Value are means ± standard deviation
* Significant at $p < 0.05$ level.
** Significant at $p < 0.01$ level.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

TAble 37: Average sulphate sulplur content in Roots and Shoots (per cent dry weight) of the selected species in control and polluted samples at different intervals

	Site	Days after sowing				
		20	40	60	80	100
C. arietinum	P	0.173±0.03	0.270±0.05	0.277±0.03	0.307±0.02	0.244±0.01
	C	0.166±0.05	0.192±0.03	0.192±0.02	0.222±0.04	0.172±0.03
	P.V.	+(4)N.S	+(15)N.S.	+(44)**	+(28)**	+(44)**
L. culinaris	P	0.207±0.02	0.269±0.04	0.325±0.03	0.380±0.02	0.255±0.01
	C	0.171±0.03	0.220±0.02	0.225±0.04	0.277±0.05	0.199±0.02
	P.V.	+(21)*	+(22)*	+(44)**	+(37)**	+(28)**
P. sativum	P	0.222±0.03	0.313±0.02	0.385±0.06	0.356±0.06	0.300±0.02
	C	0.179±0.02	0.230±0.03	0.260±0.03	0.223±0.04	0.200±0.04
	P.V.	+(24)*	+(36)**	+(48)**	+(60)**	-(50)**

Value are means ± standard deviation
* Significant at $p < 0.05$ level.
** Significant at $p < 0.01$ level.
N.S. Non significant.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

in 80 days old plants while in the other two species the maximum amount of sulphur amounting up to 44 per cent in both cases was recorded in 60 days old plants.

3.6 SEED ANALYSIS

The seeds were analysed for their protein, nitrogen and phosphorus contents following the method given by Lowry *et al.* (1951), and nitrogen and phosphorus by the method of Lindner (1944) and Fiske and Subba Row (1925). The data obtained was statistically analysed and presented in Table 38. A glance at the data reveals that there was a significant loss in protein, nitrogen and phosphorus contents in the seeds of all the three species. A maximum of 28 per cent of protein loss (highly significant) was recorded in *L.culinaris* . In *C.arietinum* the protein level decreased by 25 per cent in seeds due to pollution, while the seeds of *P.sativum* lost 20 per cent of their protein under coal-smoke pollution. The nitrogen content of seeds decreased significantly under the pollution stress in all the three species. The maximum of 25 per cent loss was noted in *C.arietinum* and *P.sativum*, while there was a 12 per cent loss in *L.culinaris*. The phosphorus content of seeds decreased in the polluted population compared to control, to a highly significant level. In case of *C.arietinum* the maximum loss in phosphorus content was noted as 42 per cent while in case of *P.sativum* and *L.culinaris* a loss of 34 per cent and 26 per cent was observed respectively.

Table 38: Data on seed anlysis (Protein, Nitrogen and Phosphorous content) in control and polluted samples of the selected species

Species	Site	Protein Content in seed	Nitrogen Content in seed	Phosphorus content in seed
C. arietinum	P	17.0±2.6	3.0±0.41	0.208±0.04
	C	22.6±2.5	4.0±0.79	0.360±0.03
	P.V.	-(25)**	-(25)**	-(42)**
L. culinaris	P	18.4±2.8	3.5±0.52	0.217±0.02
	C	25.0±1.9	4.5±0.66	0.293±0.03
	P.V.	-(28)**	-(22)**	-(26)**
P. sativum	P	16.0±1.8	3.0±0.63	0.198±0.04
	C	20.0±1.9	4.0±0.69	0.300±0.03
	P.V.	-(20)**	-(25)**	-(34)**

Value are means ± standard deviation
** Significant at $p < 0.01$ level.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

3.6.1 Nitrogen

The estimation of nitrogen in the selected crops at different intervals revealed that all the three crops showed depletions in nitrogen content at all stages of growth compared to control (Table 39). The loss in nitrogen increased with the increasing age of the plant. Among the three pulse crops studied Lens suffered the heaviest loss amounting up to 43 per cent at the harvest stage followed by *Pisum* (32 per cent) and Cicer (30 per cent). The loss in nitrogen in *Pisum* was comparatively heavy in the early stage of growth than at the later stages, attaining the maximum loss at 60 days old plant while Cicer suffered its maximum loss in 80 days old stage and Lens at its harvest stage.

3.6.2 Phosphorus

The estimation of phosphorus in plant samples of the selected crops at different intervals had revealed that all the three crops suffered severe depletion of phosphorus at all stages of growth under coal smoke pollution (Table 40) except Lens which recorded a significant increase at the seedling stage at the pollution rich site, although this crop faced the heaviest loss in phosphorus at a later stage (35 per cent) compared to the other two. Cicer lost 26 per cent of phosphorus at 60 days old stage, a highly significant amount but at other stages of growth the loss in phosphorus amounted only to a moderate level. *Pisum*, on the other hand, lost highly significant level of phosphorus under coal smoke pollution at all stage of growth except the seedling stage, in which the variation in phosphorus content was only nominal and non-significant as compared to control.

3.6.3 Potassium

The analysis of potassium in plant samples of the selected crops revealed that this element accumulated in all the three crops to various degrees at different stages of growth (Table 41). The accumulation of potassium occurred to its maximum in Lens (35 per cent) over the control at 60 days old stage, although it decreased later gradually to touch 14 per cent at the harvesting stage, an amount proved to be non-significant in statistical sense. In the other two crops, the level of potassium at the seedling stage was only nominal and non-significant but it became significant later and touched the minimum of 1[illegible] per cent (non-significant) at the harvest stage i *P.sativum*.

Table 39: Data on the Nitrogen content (per cent dry weight) in plant samples of the selected species at control and polluted sites at different intervals

Species	Site	Days after sowing				
		20	40	60	80	100
C. arietinum	P	3.20±0.26	4.50±0.33	5.10±0.22	3.50±0.21	2.50±0.15
	C	3.50±0.20	5.50±0.44	6.50±0.34	5.00±0.25	3.50±0.22
	P.V.	-(9)**	-(18)**	-(23)**	-(30)**	-(29)**
L. culinaris	P	2.80±0.23	3.50±0.29	4.30±0.29	2.50±0.28	2.00±0.22
	C	3.30±0.25	4.50±0.33	5.40±0.35	4.00±0.36	3.50±0.34
	P.V.	-(15)**	-(22)**	-(27)**	-(38)**	-(43)**
P. sativum	P	2.50±0.42	4.00±0.55	5.20±0.22	3.50±0.25	2.50±0.24
	C	3.00±0.35	5.80±0.68	7.60±0.33	5.00±0.35	3.50±0.35
	P.V.	-(17)**	-(31)**	-(32)**	-(30)**	-(29)**

Value are means ± standard deviation
** Significant at p < 0.01 level.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

Table 40: Data on the phosphorus content (per cent dry weight) in plant samples of the selected species at control and polluted sites at different intervals

Species	Site	Days after sowing 20	40	60	80	100
C. arietinum	P	0.277±0.05	0.301±0.05	0.351±0.08	0.190±0.03	0.150±0.03
	C	0.320±0.04	0.386±0.09	0.472±0.07	0.239±0.06	0.179±0.02
	P.V.	-(13)*	-(22)*	-(26)**	-(21)*	-(16)*
L. culinaris	P	0.152±0.05	0.180±0.03	0.240±0.03	0.149±0.03	0.104±0.02
	C	0.116±0.02	0.254±0.05	0.350±0.05	0.231±0.04	0.130±0.03
	P.V.	+(24)*	-(29)*	-(31)**	-(35)**	-(20)*
P. sativum	P	0.102±0.05	0.365±0.06	0.390±0.05	0.242±0.02	0.085±0.03
	C	0.110±0.05	0.425±0.03	0.485±0.04	0.315±0.05	0.126±0.03
	P.V.	-(7)N.S.	-(14)**	-(20)**	-(23)**	-(33)**

Value are means ± standard deviation
* Significant at $p < 0.05$ level.
** Significant at $p < 0.01$ level.
N.S. Non significant.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

Table 41: Data on the of potassium content (per cent dry weight) in plant samples of the selected species at control and polluted sites at different intervals

Species	Site	Days after sowing				
		20	40	60	80	100
C. arietinum	P	0.600±0.13	0.750±0.09	0.870±0.09	0.650±0.08	0.525±0.06
	C	0.700±0.18	0.955±0.09	1.170±0.08	0.910±0.09	0.655±0.07
	P.V.	-(14)N.S	-(21)*	-(26)**	-(29)**	-(20)**
L. culinaris	P	0.530±0.06	0.621±0.09	0.700±0.12	0.601±0.05	0.450±0.08
	C	0.660±0.08	0.930±0.12	1.080±0.15	0.769±0.08	0.525±0.09
	P.V.	-(20)*	-(33)**	-(35)**	-(22)**	-(14)N.S.
P. sativum	P	0.610±0.08	0.780±0.07	0.815±0.12	0.656±0.07	0.525±0.08
	C	0.695±0.09	0.995±0.09	1.190±0.15	0.809±0.05	0.605±0.06
	P.V.	-(12)N.S	-(22)**	(32)**	-(19)*	-(13)N.S.

Value are means ± standard deviation
* Significant at $p < 0.05$ level.
** Significant at $p < 0.01$ level.
N.S. Non significant.
P = Polluted site, C = Control site,
P.V. = Per cent variation, G.I. = Growth index.
(+) / (-) indicate per cent increase or decrease over control.

DISCUSSIONS

4. DISCUSSIONS

4.1 GROWTH ACTIVITY

Hazards of air pollution to green vegetation particularly of SO_2, NO_3, CO, CO_2 and particulate matters have been reported by a number of workers from different parts of the globe including the tropical climatic regime. Some of the relevant works on this aspect, include that of DeOng (1946), Brennan *et al.*(1970), Costonis (1970, 1971), De Cormis *et al.* (1970), Biscoe *et al.*(1973), *Division et al.*(1973), Evans (1973), Chaphekar and Karabhari (1974), Leone and Green (1974), Bennett and Runeckles (1977), Capron and Mansfield (1976, 1977),Cowling and Lockyer (1976), MacLean *et al.*(1977), Oshima *et al.* (1977), Zaidi *et al.*(1979), Ashenden and Williams (1980), Ashmore *et al.*(1980), Borka (1980), Ferguson and Lee (1980), Ghouse *et al.*(1980), Lal and Ambasht (1980), Raza and Bano (1981), Periasamy and Vivekanandan (1982 Vollmer *et al.*(1982), Pandey (1985), Murty and Anuradha (1984). The earlier works on air pollution on a variety of taxa including the wasteland weeds include that of Gupta (1981), Gupta and Ghouse (1987),Ghouse and Amani (1979), Ghouse and Khan (1983 and 1984), Ghouse *et al.* (1984 a,b) Ghouse *et al.* (1980, 1984a, 1984b, 1994). Recently Thomas (1984) has reviewed the works related to gas damage to plants.

4.1.1 Root Growth

The observations recorded in the present investigation revealed that the three pulses studied faced severe losses in root growth as a result of air pollutants prevailing over the experimental sites. A similar severe loss in root growth has been reported by Khan (1985) in case of *Anagallis arvensis*, *Chenopodium album*, *Melilotus indica* and *Cassia tora*. A significant loss in root growth has also been noted in *Abutilon indicum*, *Achyranthes aspera*, *Calotropis procera*, *Cassia occidentalis*, *Croton bonplandianus* and *Xanthium strumarium* by Amani (1982), in *Melilotus indica* and *Solanum nigrum* by Ghouse and Khan (1983, 1984)and in brinjal and okra by Gupta(1981). There are many others who have also noted loss in root length in different species due to different air pollutants under laboratory conditions viz., in *Triticum* (Pandey and Rao, 1978), *Crotolaria, Cyanopsis* (Chaphekar and Boralkar, 1979), alfalfa (Singh and Rao, 1979), *Allium sativum* (Sharma *et al.*, 1979), *Robinia pseudacacia* and *Acer saccharinum* (Swannapinunt and Kozlowski, 1980), *Cucumis sativus* and *Nicotiana tabacum* (Mejstrick, 1980), Blackgram (Raza and Bano, 1981) and in *Vigna radiata* (Pandey, 1985).

4.1.2 Shoot Growth

The shoot length in all the three pulses presently studied, has incurred heavy losses due to air pollutants prevailing over the experimental site depending on the age of the plant.

Growth reductions in shoot length has been reported by several others in a variety of plant species due to the adverse effects of different air pollutants including that of ammonia and cement dust (Cowling and Lockyer, 1976; Crittenden and Read, 1978, 1979; Pandey and Rao, 1978; Chaphekar and Boralkar, 1979; Oblisami *et al.* 1978; Swannapinunt and Kozlowski, 1980; Gupta, 1981; Raza and Bano, 1981; Amani, 1982; Khan, 1982; Vollmer *et al.*, 1982; Ghouse and Khan, 1983, 1984; Khan and Khair, 1984, 1985a, 1985b and Pandey, 1985).

4.1.3 Green Area

Green area has shown significant reduction in number of leaves plant^{-1}, in response to coal smoke pollution. The loss in total leaf area plant^{-1} happened to be highly significant in *C.arietinum* and *L.culinaris* but in *P.sativum* the leaf area plant^{-1} increased under coal smoke pollution which appears to be unique to this species.

Recently, considerable reduction in leaf area due to pollution hazard has been reported in *Achyranthes aspera* and *Cassia occidentalis* to the tune of 90.43 and 49.15 %, respectively,by Amani (1982). Similarly, a significant reduction in total photosynthetic area in polluted locality has been noted in *Abutilon indicum*, *Calotropis procera*, *Croton bonplandianus* and *Xanthium strumarium* by Amani

(1982). *Vigna sinensis* and *Dolichos lablab* (Amani and Ghouse, 1978), *Solanum nigrum*, (Ghouse and Khan, 1984), *Gomphrena celosioides* (Khan and Khair, 1985 b), brinjal and okra (Gupta, 1981) and grassland weeds (Khan, 1985). Leaf area damage proportional to the leaf number meter^{-2} of grassland vegetation at an urban site attributable to environmental pollution has been reported by Raza and Chapala (1984).

Raza and Bano (1981) have noted a considerable reduction in leaf number in blackgram T-9 cultivar and found that younger leaves were more susceptible to ammonia pollution than the older ones. Murty and Anuradha (1984) have noted reduction in leaf size of *Cassia tora* due to dust pollution from a ferro-alloys factory.

Reduction in leaf number and area leaf^{-1} due to various pollutants has been reported by Ashenden (1979) in *Dactylis glomerata*, Oblisami *et al.* (1978) in Cotton, Pandey and Rao (1978) in wheat, Ashenden and Williams (1980) in *Lolium multiflorum* and *Phleum pratense*, Constantinidou and Kozlowski (1980) in *Ulmus americana*. The reduction in leaf size due to pollution load has also been reported in various cases by Ayazloo *et al.* (1980), Mejstrik (1980) and Sharma *et al.*(1980).

4.2 BIOMASS

The root and shoot biomass, and the phytomass of all the three pulse crops studied have yielded a similar trend of results having marginal loss in seedling stage and highly significant losses later. The remarkable loss in dry matter accumulation in shoot axis due to SO_2 fumigation under controlled conditions has been noted in a number of cases viz. *Lolium perenne* (Bell and Clough, 1973; Bleasdale, 1973; Ayazloo *et al.*1980), wheat (Pandey and Rao, 1978), *Abelmoschus*, *Crotolaria*, *Cyanopsis* and *Trigonella* (Chaphekar and Boralkar, 1979) and *Vigna radiata* (Pandey, 1985). Raza and Bano (1981) have noted reduced biomass in blackgram on fumigation with ammonia gas. Murty and Anuradha (1984) have noted considerable reduction in phytomass of *Cassia tora* due to dust pollution from a ferro-alloys factory. The phytomass reduction has been noted in certain wayside weeds by Amani (1982), Ghouse and Khan (1983, 1984), Khan and Khair (1984, 1985 a,b), in certain vegetable crops by Gupta (1981) and in certain grassland weeds by Khan (1985).

4.2.1 Primary Productivity

The net primary productivity of all the three pulse crops under investigation, has been found to undergo a highly, significant reduction under the influence of coal smoke pollution. However, the loss in net productivity of the seedlings of all the three crops has been found to be slightly lower under coal smoke pollution than in control to a non-significant level. Bell *et al.* (1979) reported a 53% reduction in dry weight of *Lolium perenne* after 40 days exposure to 0.12 ppm SO_2. They also reported that the effect happened to be heavy on relative growth rate at early stage on long term fumigation and thus concluded that young plants might have greater susceptibility to the pollutants than the older one. Later in 1985, Khan has however found that the loss happened to be higher in older plants of *Anagallis arvensis*, *Chenopodium album*, *Melilotus indica*, *Cassia tora* and *Lindernia crustacea* than in he younger ones of the concerned species. Jones and Mansfield (1982) have also noted a similar trend to pollution effect in their studies on *Phleum pratense*.

Loss in primary productivity of certain vegetable crops under the influence of pollutants arising out of coal burning has been note by Gupta (1981). Raza and Bano (1981) have noted a significant loss in the net primary productivity of blackgram, in 75 day old crop under the stress of ammonia fumigation.

4.3 **REPRODUCTIVE GROWTH ACTIVITY**

All the three pulse crops studied have shown a considerable reduction in floral bud formation, fruit development and seed set. Several others have also noted highly significant loss in floral bud formation, fruit development and seed set in a variety of plant species investigated by them in the same site under coal smoke pollution (Khan, 1982; Khan, 1985; Amani, 1982; Gupta, 1981, Mahmooduzzafar, 1991).

In an interesting study of SO_2 fumigation on tulip in regard to relative sensitivity of floral axis, petals and leaves, the highest response was observed in floral axis followed by petals and leaves by Taniyama and Arikado (1970). Similarly, flower size, weight and number of florets, total leaf area were found reduced as the severity of injury increased in hydrogen fluoride fumigated gladiolus (Brewer *et al.* 1966). Reduction in the yield of tomato and bean plants subjected to cement dust has been noted upto 13% and 40% respectively (Darley, 1966). Considerable loss in fruit set due to coal firing has been reported in certain vegetables (Gupta, 1981) weeds (Amani, 1982) and a timber tree of the region (Khan, 1982). Loss in fruiting, attributable to air pollutants has been reported in apple, plum, prune and peach by Miller *et al.*(1948) orange and citrus by Leonard and Graves(1966, 1970), citrus by Thompson and Taylor (1966, 1969), tomato by Manning and Vardaro (1974) and in *Dalbergia sissoo* by Ghouse and Amani (1979) and Khan (1982).

4.3.1 Reproductive capacity

Due to reduced floral development, fruit set and seed output, the harvest index is falling by 21-28 % in the crops investigated. This was further aggravated by low viability and germination percentage. The reproductive capacity of the species gets affected to the extent of 57% in *P. sativum*, 49% in *C. arietinum* and 37% in *L. culinaris*, all on statistical analysis have proved to be highly significant. In a recent study Khan in (1982) has reported, a high loss of reproductive capacity in one of the forest trees of the region due to coal smoke pollution.

4.4 BIOCHEMICAL ANALYSIS

4 4.1 Chlorophyll pigments

Chlorophylls, the green pigments of plants are the most important pigments responsible for the conversion of light energy into chemical energy and are thus active in the process of photosynthesis. Chlorophyll molecule has a cyclic tetrapyrrolic structure(Porphyrin), with an isocyclic ring containing a magnesium atom at its centre and a phytol chain attached to it. Chloroplast of higher plants always contain two types of chlorophyll. One is invariably chlorophyll 'a', and the other is chlorophyll 'b', which has an aldehyde group instead of a methyl group attached to ring II. Most higher plants contain about twice as much chlorophyll 'a' as chlorophyll 'b'. Carotenoids, on the other hand are also found in varying amounts in nearly all higher plants and are believed to be vital for two important functions: (a), they protect against the photo-oxidation of chlorophylls and (b), they absorb and transfer light energy to chlorophyll 'a' (Devlin and Witham, 1986).

The pigment analysis undertaken in the present study reveal that the ratio of chlorophyll 'a' and chlorophyll 'b' under normal conditions ranges from 1:0.382 in *Cicer arietinum,* 1:0.598 in *Lens culinaris* and 1:0.840 in *Pisum sativum*. This goes against the common belief that chlorophyll 'a' is twice the number of chlorophyll 'b' as mentioned by Lehninger *et al.* (1993). In a recent study Saheed (1995) has found a similar situation in some tropical trees in which the ratio of chlorophyll 'a' and 'b' ranged from 1:0.65 to 1:0.76. The pigment contents when analysed, have revealed that all the investigated species under go considerable loss in their coloured pigments under coal-smoke pollution. The loss in chlorophyll pigments under sulphur dioxide pollution has been a common observation by almost all workers in the past both under controlled as well as under field conditions (Wellburn et *al.*, 1972; Malhotra, 1977, Pandey and Rao, 1978; Prasad and Rao, 1982; Devi and Patel, 1983; Pandey, 1983, Irving and Miller, 1984; Malhotra and Khan, 1984; Sharma and Rao, 1985; Singh *et al.*, 1985 Yunus *et al.*, 1985; Kumar and Yadav, 1986; Nandi *et al.*, 1986; Singh and Rao, 1986; Agrawal *et al.*, 1987; Chand and Kumar, 1987; Gupta and Ghouse, 1987; Beg and Farooq, 1988; Farooq *et al.*, 1988; Singh and Rao, 1988;Vijayan and Bedi, 1988; Prakash *et al.*, 1989a; Singh, 1989; Saquib and Ahmad, 1991; Sharma and Prakash, 1991; Ghouse *et al.*, 1994; Ramasubramanian *et al.*, 1993; Sabu *et al.*, 1993; Saarinen and Liski, 1993).

The reduction in chlorophyll content has usually been brought about by pollution load in two ways. First the rate of increase gets affected by limiting the formation of these pigments and secondly by bringing about accelerated decolourization and degeneration of these pigments. The total loss in pigment due to pollution thus becomes two fold. The reduction in chlorophyll contents by sulphur dioxide, hydrogen fluoride and hydrogen chloride is a generally accepted fact, as these compounds create low pH of the medium which eventually brings about decolourization and degradation (Puckett *et al.*, 1973; Devi and Patel, 1983). However, in a recent study Saheed (1995) has reported in *Ficus bengalensis* that it experienced a significant gain in the amount of chlorophyll pigments and carotenoids under coal smoke pollution, instead of undergoing any loss. A similar situation of increased chlorophyll content has been come across by Murray (1990) in two species of Eucalyptus under SO_2 pollution. Earlier, Murray and Wilson (1988) have also demonstrated the increase in chlorophyll concentration in *Eucalyptus tereticornis* when exposed to concentrations of SO_2 and hydrogen fluoride. Doley(1988) has found increase in chlorophyll concentration in four species of Pinus under fluoride pollution. Devi and Patel (1983) have also found increased sugar production in plants in which there has been an increase in chlorophyll concentration under pollution stress.

Among the chlorophyll pigments analysed, chlorophyll 'a' suffered greater loss in all the three crops investigated. The original ratio of chlorophyll 'a' and chlorophyll 'b' under normal atmosphere, thus get disturbed and altered. Under pollution stress the ratio of the chlorophyll 'a' to chlorophyhll 'b' ranges from 1:0.372 to 1:0.454 in *C. arietinum*, 1:0.550 to 1:0.780 in *L. culinaris* and 1:0.720 to 1:0.960 in *P. sativum*. This higher ratio of cholorphyll 'b' to that of chlorophyll 'a' compared to the respective controls mainly due to higher loss of chlorophyll 'a' both in its formation and degeneration compared to the former. A similar situation has been recorded by Saheed (1995) in *Cassia fistula* and *Tamarindus indica* both happened to be leguminous trees, and attributed to the higher sensitivity of chlorophyll 'a' to coal smoke pollution compared to non-leguminous Azadirachata *indica* and *Ficus religiosa*.

However, Saheed (1995) has found a reverse picture of chlorophyll 'b' in *Azadirachta indica* and *Ficus bengalensis* due to higher loss of chlorophyll 'b' than chlorophyll 'a' in these two species. Saheed (1995) has further discovered that in the case of *Ficus bengalensis*, the position of chlorophyll 'b' becomes stronger due to its higher production than chlorophyll 'a' under coal smoke pollution.

The ratio of total chlorophyll inthe investigated species decreased under coal-smoke pollution by higher loss of chlorophyll 'a' than chlorophyll 'b'. This may be due to high sensitivity of chlorophyll 'a' to SO_2 pollution as interpreted by earlier workers (Sunderland, 1967; Malhotra, 1977; Kondo *et al.*, 1980; Choudhary and Sinha, 1982; Periasamy and Vivekanandan, 1982; Singh and Rao, 1986; Gupta and Ghouse, 1987, Khan and Usmani, 1988; Prakash *et al.*, 1989 b; Singh, 1989; Lone, 1993; Saheed. 1995). The greater loss of chlorophyll 'a' than 'b' has been interpreted in more than one way and it is ascribed to the inactivation of various enzymes associated with the synthesis and action of chlorophyll 'a'. Knudson *et al.*, (1977) suggested the following possibilities for the reduction of chlorophyll 'a' to chlorophyll 'b' ratio due to the exposure of plants to ozone.

(a) Chlorophyll 'a' may degrade more rapidly than chlorophyll 'b' and (b) either the synthesis of chlorophyll 'a' may be reduced or that of chlorophyll 'b' may be increased. Chlorophyll 'b' may be formed from chlorophyll 'a', and chlorophyll 'a' may undergo rapid degradation as compared to chlorophyll 'b' in senescent leaves.

The higher sensitivity of chlorophyll 'a' to pollution stress hampers the plant growth considerably as it plays a very important role in the process of photosynthesis (Malhotra, 1977). Comparatively higher losses of chlorophyll 'b' has been found in case of *Azadirachta indica* and *Ficus religiosa* by Saheed, (1995). Devi and Patel (1983) have also found higher reduction in chlorophyll 'b' in *Azadirachta indica* working on the effect of air pollution emitted by a fertilizer complex situated in Baroda.

4.4.2 Carotenoids

Carotenoids are lipid compounds that are distributed widely in both animals and plants and range in colour from yellow to purple. Carotenoids are present in variable concentrations in nearly all higher plants. They absorb light at wave lengths other than those absorbed by the chlorophylls and thus act as supplementary light receptors. The major carotenoid found in plant tissues is the orange-yellow pigment, β carotene, which is generally accompanied by varying amounts (0 to 35 per cent) of α carotene (Mackinney, 1935). The probable roles of carotenoids are (1) they protect against the photo oxidation of chlorophylls and (2) they absorb light and transfer the energy to chlorophyll 'a' (Devlin and Witham, 1986).

The observations recorded in the present study on the carotenoid contents show considerable losses of carotenoids in the folliage of all the three pulse crops leading to highly significant levels in certain stages of growth. In a recent study on some tropical trees exposed to coal-smoke pollution, Lone (1993) and Saheed (1995) have also found a similar trend of behaviour of carotenoids. Nouchi *et al.*, (1973) and Prasad and Rao (1982) have also noted considerable loss of carotenoids under pollution stress.

The ratio (Table 31) of total chlorophyll to carotenoids in the investigated species varies from 1:0.173 to 1:0.327 in the control and from 1:0.182 to 1:0.349 in the polluted site. In *C. arietinum* the average ratio of total chlorophyll and carotenoids occurs at 1:0.226 in control and the ratio of carotenoids increases to 0.245 in polluted samples; in *L. culinaris* it raises from 0.290 to 0.312 and in *P. sativum* it becomes 0.428 from 0.395 due to coal smoke pollution.

About 14 per cent loss in chlorophyll contents in average due to coal smoke pollution boost the ratio of carotenoids in the selected species. A similar picture of carotenoids has been observed by Saheed (1995) recently in a leguminous tree, *Tamarindus indica*. Leaving aside this lonely report of Saheed (1995), there appears to be no work in the past regarding the ratio of carotenoids to chlorophylls under pollution stress.

4.4.3 Nitrogen

Nitrogen is one of the essential nutrients for the plants and perhaps nitrogen's most recognised role in plants is its presence in the structure of protein molecules. In addition, nitrogen is found in such important molecules as purines, pyrimidines, porphyrins and coenzymes. Purines and pyrimidines are found in the nucleic acids RNA and DNA and are essential for protein synthesis and transfer of genetic material (Devlin and Witham, 1986). The porphyrin structure is found in such metabolically important compounds such as the chlorophyll pigments and cytochromes,essential in photosynthesis and respiration. Coenzymes are essential in the function of many enzymes. In addition to its absorption generally in the form of NO_3, nitrogen is also taken up as NH_4^+. Once inside the plant, nitrogen is reduced and incorporated into diverse organic compounds (Beevers and Hageman, 1969). Its deficiency may result in stunted growth and yellowing of leaves on account of loss of chlorophyll. It is an established fact that the foliar level of different inorganic elements are affected by (i) uptake from the soil and atmosphere(2) translocation to and from other tissues within plant(3) loss by leaching or volatalization (Van den Driessche, 1974; Miller, 1984; Johnson et al., 1985). Further uptake, accumulation and distribution of various mineral nutrients in the plant body are influenced by several factors such as climate, season, time of the day, age of the tree and foliage, type of the tree species and soil conditions (Bazilevic and Rodin, 1964; Ovington 1968; Evans, 1979).

The nutritional effect of NO_2 on the plant in nitrogen deficient conditions has been reported by several workers in the past (Troiano and Leone, 1977; Troiano 1978; Yoneyama *et al.*, 1980; Srivastava and Ormrod, 1984; Okano and Totsuka, 1986; Rowland *et al.*, 1987; Wingsle *et al.*, 1987; Sabaratnam *et al.*, 1988; Ramasubramanian *et al.*, 1993).

The observations recorded in the present study on nitrogen content shows that there has been a severe depletion of nitrogen in all the three crops at all stages of growth under the stress of coal smoke pollution.

The decrease in nitrogen content in plants under pollution stress is a common observation. In a recent study Saheed (1995) has observed a significant loss in the nitrogen content of *Tamarindus indica*, a leguminous tree in all seasons under the pollution stress. The earlier reports in some annual crops (Pandey and Rao, 1978; Mishra, 1980; Elkiey and Ormrod, 1981; Sharma and Rao, 1985; Prakash et al 1989 a) as well as in some trees like *Diospyros melanoxylon*, *Lagerstroemia parviflora* and *Zizyphus nummularia* growing under field conditions around a coal fired power plant have shown a severe depletion of nitrogen in the polluted population (Pandey, 1983; Zech *et al.*, 1990/91). However, there are a few reports showing significant amount of nitrogen increase in the different plant parts under coal smoke pollution (Malkonen, 1974; Evans, 1979; Garsed *et al.* 1981; Lone, 1993, Saheed 1995).

4.4.4 Phosphorus

Phosphorus is present in the soil in two general forms, organic and inorganic. It is the inorganic form of phosphorus which is available to the plants. However, phosphorus bound in organic compounds is eventually liberated through decomposition and is released in the inorganic form which is readily taken up by the plants. Further, phosphorus is absorbed by roots both as monovalent (H_2PO_4) and divalent (HPO_4-) anions. The quantity of either ion present in the soil is dependent upon pH of the soil solution. The lower pH favours H_2PO_4 and higher pH, HPO_4, ions (Devlin and Witham, 1986).

The observations (Table 40) regarding the concentration of phosphorus in the different investigated species in the present study show that there has been a deep fall in the level of phosphorus under pollution stress.

The severe losses of phosphorus content recorded at different stages of growth coincide with the earlier reports of many workers in different plant forms like, *Triticum aestivum* (Pandey and Rao, 1978) *Arachis hypogaea* (Mishra, 1980); *Pisum sativum* (Garsed *et al.* 1981); *Diospyros melanoxylon*, *Lagerstroemia parviflora* and *Zizyphus nummularia* (Pandey, 1983); *Festuca arundinacea* (Flagler and Youngner, 1985) and *Fagus sylvatica* (Zech, *et al.*,1990/91). The decreased phosphorus concentrations in the plants growing under SO_2 pollution in the present study may be due to the inhibition in certain important enzymatic activities involved in 'P' metabolism. Further, it is expected that plants under stress physiological conditions are likely to lose much energy to combat the hazards. It, therefore, opens a challenge to the pollution problem indicating the possibility of management c pollution stress through manipulation of 'P' balance in the involved system. Moreover, the nutrient supplying capacity of the soil with respect to 'P' seems to be less (Table 40) as reported earlier by Agrawal *et al.* (1985). Fried and Broeshart (1967) put forth their hypothesis, that SO_2 induced acidity may cause greater solubility and mobility of soil constituents particularly 'P' which may leach from the rooting zone and become unavailable for plant growth.

4.4.5 Potassium

The potassium is required in large amounts for plants and, unlike nitrogen and phosphorus, it does not form a stable structural part of any molecule in a plant ell. The highest concentration of potassium is found in the meristematic regions of the plants. Potassium is essential for the activation of the enzymes and is involved in the synthesis of certain peptide bonds in carbohydrate metabolism. It also enhances the incorporation of amino acids into proteins (Webster, 1956). The enzymes that require 'K' as an activator include fructokinase, pyruvic acid kinase and transacetylase Nason and Mc Elroy, 1963). Potassium (K) is essential for some vital metabolic processes including glycolysis, oxidative phosphorylation and adenine synthesis (Evans and Sorger, 1966). It is actively involved in the translocation of solutes moving across the sieve plates by electro-osmosis (Salisbury and Ross, 1986). Its role is inevitable in the physiological processes like photosynthesis, chlorophyll development and the water balance of the leaves. The best known function of 'K' is its role in stomatal opening and closing (Fischer and Hsiao, 1968). Its deficiency causes necrosis, rosette or bushy habit of growth and weakening of stems and decreases the resistance against pathogens.

Potassium is present in the soil in a non exchangeable (fixed) form, exchangeable form, and in a soluble form, which always remain in equilibrium and a change in the concentration of any one of the consstituents will cause a shift towards stabilization. For example, depletion of the soluble 'K' in the soil by he plant and soil micro organisms will cause the slow release of fixed 'K'. This situation is desirable because absorbed and fixed 'K' which is not readily leached from the soil can be available to the plants.

The data regarding the concentration of potassium in the foliage of different investigated species under pollution stress is summarized in Table 41. The accumulation of potassium in all the three pulse crops investigated in the present study is in agreement with the earlier report of Saxe (1983) who found a similar increase in potassium level in the plants exposed to SO_2 pollution and also with the finding of Saheed (1995) who recorded increase in potassium content in the foliage of leguminous trees viz. *Cassia fistula* and *Tamarindus indica*. However, Zech *et al*., 1985, Lone (1993) and Saheed (1995) have reported a severe depeletion of this important element in plants which suffered from pollution stress.

4.4.6 Protein

The proteins are the most vital components of the living systems and their most significant influence resides in the fact that many are functionally active as enzymes which are vital for the rapid rates of biochemical reactions. Proteins also act as natural hydrogen ion buffers and structural components of the cells. The literature pertaining to the impact of SO_2 on the protein contents of the plants is well documented. In a recent communication Rao and Dubey (1990 a,b) reported significantly reduced protein contents in the foliage of several plant species viz. *Azadirachta indica, Calotropis procera, Cassia siamea, Dalbergia sissoo, Ipomoea fistulosa, Mangifera indica Syzygium cumini* and *Zizyphus mauritiana* growing in field conditions around an industrial area. In an earlier investigation on certain tropical tree species, Beg and Farooq (1988) observed that SO_2 concentrations which produced no visible injury, decrease the protein contents in *Ficus rumphi, Holoptelea integrifolia, Mangifera indica, Psidium guajava and Syzygium cumini,* but no change was observed in the *Pithecolobium dulce* while *Ficus bengalensis* shows elevated protein contents.

The present investigation on three pulse crops has revealed that the protein content decreases in root and shoot systems as well as in the seeds to a highly significant level in the polluted population. Since pulses are cultivated for their protein content, the loss in protein to the extent of 28 percent in lentil, 25 percent in gram and 20 percent in peas is a matter of great concern in developing countries like India in which protein deficiency in growing children is a common scene. There are several reports of the past that recorded reduction in protein content in plants under the stress of SO_2 pollution (Fischer, 1971; Godzik and Linskens, 1974; Mudd, 1975; Constantinidou and Kozlowski, 1979; Malhotra and Sarkar, 1979; Grill *et al.* 1980; Robe and Kreeb; 1980, Percy and Riding, 1981; Rao and Dubey, 1990 b; Saheed, 1995). The reports showing the increase in protein content under pollution stress is also not uncommon in literature (Prasad and Rao, 1982; Saxe, 1983; Murray, 1984; Rao and Dubey, 1990a; Lone, 1993; Saheed, 1995).

4.4.7 Sulphur

Sulphur is an essential element as it forms a constituent of number of amino acids (Devlin and Witham. 1986). The inorganic sulphur taken up by the plants enter the system in organic form. The excess of sulphur is usually accumulated in sulphate form (Thomas *et al.* 1950;Jones, 1962; Faller *et al.* 1970; Hallgren. 1978; Thoiron *et al.* 1981; Cram, 1983; Pandey, 1983; Legge *et al.* (1988) and get eliminated in due course of time. When they are stored in leaves, they get eliminated when leaves fall and similarly those stored in bark get eliminated when the bark peels off year after year (Garsed. 1984; Rennenberg, 1984; Lone, 1993).

The plants in general, when they are grown in sulphur rich atmosphere absorb excess amount of the element and accumulate what has not been incorporated in the organic system in different parts. There are a number of reports regarding the response of different plants to SO_2 exposure under the control conditions (Bleasdale, 1952; Tingey *et al.* 1971; Khan and Malhotra, 1977; Pandey and Rao, 1978; Lauenroth *et al.* 1979; Garsed *et al.* 1981; Elkiey and Ormrod, 1981; Koziol and Whatley, 1984; Jager *et al.* 1985; Beg and Farooq, 1988, Farooq *et al.* 1988; Vander Stegen and Myttenaere, 1991; Wookey and Ineson, 1991; Fuehrer *et al.* 1993) as well as to SO_2 enriched ambient atmosphere under field conditions (Jones *et al.* 1974; Wood and Bormann, 1975; Ziegler, 1975; Legge *et al.* 1977; 1980; 1988; Pandey, 1983; Trilica *et al.* 1985; Amundson *et al.*, 1986; 1990; Zech et al, 1985. 1990/91; Rao and Dubey 1990 a,b).

When the plants are exposed to SO_2, the gas enters the leaf system along with the air through the stomata and get dissolved in water and affects the working of the organic system of the cells, disturbing the pH of the medium as well as interfering with the metabolic activities of the cells (Malhotra and Sarkar, 1979; Garsed *et al.* 1981; Trilica *et al.* 1985 Rao and Dubey, 1990a).

The present study to evaluate the sulphur content of the leaves reveals that the selected species have absorbed excess sulphur in the form of SO_2 and accumulated it in roots and shoots. The amount of sulphur accumulated depends on the species. Similar observations have been recorded by a number of earlier workers in various broad leaved as well as in conifers (Prasad and Rao, 1982; Pandey, 1983; Murray, 1984; Zech *et al.* 1985; Iqbal 1988; Singh and Rao, 1988; Murray and Wilson, 1990, 1991; Rao and Dubey, 1990a,b; Sharma and Prakash, 1991; Van der Stegan and Myttenaere, 1991; Zech *et al.* 1990/91;Lone and Ghouse, 1993; Kupka, 1993; Sah and Meiwes, 1993;Wulf *et al.* 1993; Lone, 1993; Saheed, 1995).

SUMMARY

5. SUMMARY

In the present study, the impact of air pollutants emitting out of the Thermal Power Plant Complex, has been studied on the growth and yield characteristics including the net primary productivity at various growth stages of the three selected leguminous crops namely *Cicer arietinum*, *Lens culinaris* and *Pisum sativum*. The crops were grown in field at a distacne of 2 km. from the Kasimpur thermal power plant (polluted site) and a controlled site was maintained at the Aligarh Muslim University, Aligarh. The power plant complex, consumes about 3192 MT of sulphur rich low grade bituminous coal daily, at an average rate. The parameters for growth included the root and shoot length, growth index, root and shoot biomass, branch number per plant, leaf number per plant, leaflet number per leaf, area per leaflet, area per leaf, total green area per plant and net primary productivity. The reproductive growth aspects comprised fruit number per plant, seed number per pod, seed number per plant, hundred seed weight, Harvest index, seed viability, seed germination and reproductive capacity. The leaves of all the three crops were analysed for photosynthetic pigments, N.P.K. content, and sulphur content while the protein content was estimated in seeds of all the three crops.

All the parameters of the selected crops have been studied for period of 100 days at an intervals of 20 days.

Shoot and Root length

Shoot length enhanced at seedling stage upto 40 days in all crops, except *C. arietinum* in which shoot growth was marginally increased up to 20 days. The root length suffered a heavy loss at all stages of growth except first stage in which loss was only marginal under coal smoke pollution.

Growth index

It was more than one up to 40 days and less than one after in shoot growth but in case of Root growth, the growth index was invariably lesser than one in all stages in all the three crops.

Number of branches per Plant

The number of branches showed highly significant loss from 60 days to the harvest stage in all the three crops under coal smoke pollution.

Number of leaves per plant

The number of leaves per plant was affected from preflowering to final stage. In case of *P. sativum* and *L. culinaris* the loss was significant even at the seedling stage.

Number of leaflet per leaf

Leaflet number per leaf decreased at all stages of growth in all the species.

Leaflet area

The coal-smoke pollution promoted leaflet size to a significant level from seedling to harvest stage in all the three crops as compared to control except *C.arietinum*, which showed a marginal reduction in leaflet area at seedling stage.

Leaf areas

The average area per leaf was affected in all the three crops. In *P.sativum*, there was a consistent increase in individual leaf area while in the other two species it was just opposite.

The total green area

The total green area per plant suffered heavy loss under coal smoke pollution.

Shoot and root biomass

All the three crops faced significant loss at all stages of growth except the seedling stage in which there was a marginal gain of shoot biomass. Root biomass suffered heavy loss at all stages of growth including the seedling stage.

Phytomass

The phytomass showed the same result as the shoot biomass at all stages of growth except the seedling stage.

Net primary productivity (N.P.P.)

N.P.P. of plant was also hampered under coal smoke pollution. The loss was maximum in *P. sativum* (46%), moderate in *C.arietinum* (44%) and low in *L. culinaris* (28%).

Yield

The maximum loss in yield was noted in *C.arietinum* (34%), and it was 32 % in *P.sativum* and 24 % in *L.culinaris*. The harvest index has revealed heavy loss in *P.sativum* (28%). The flowering as well as fruit setting was affected in all the three crops due to coal smoke pollution.

Reproductive growth activity

Number of flower per plant, number of fruit per plant, number of seed per pod, number of seed per plant and hundred seed weight were significantly affected in all the three crops under coal smoke pollution. The severity of loss in the harvest index was noted as *P. sativum* > *C. arietinum* > *L. culinaris*. Data obtained on seed viability, seed germination and reproductive capacity reveals that all the three crops suffered heavy loss, *P. sativum* facing the worst.

Biochemical analysis

The loss in Chlorophyll "a" was highly significant at all stages of growth under coal smoke pollution. While Chlorophyll "b" and carotenoids continue to decrease from flowering to the final stage in all the three crops. Unlike the chlorophylls, the carotenoids continue to form till the last stage in control as well as in the polluted population in all the three crops. Chlorophyll "a" is more sensitive to coal smoke pollution than chlorophyll "b". Chlorophyll showed higher vulnerability than carotenoids to coal smoke pollution.

Protein

The average protein content in roots and shoots in general, decreased in the polluted population with the roots having higher loss than the shoots.

Sulphate-sulphur

The increase sulphate-sulphur content in shoots was highly significant at all stages of growth, in all excepting *C.arietium* which showed a moderate increase at the seeding stage. While in roots it was only marginal up to 40 days, and later it became high under coal smoke pollution.

The nitrogen, phosphorus and protien content of seeds decreased significantly under the pollution stress in all the three species.

Nitrogen

Under the polluted atmosphere the loss in nitrogen became high with the increasing age of the plant in all the three crops, with *L.culinaris* having the heaviest loss.

Phosphorus

Severe depletion of phosphorus was recorded under coal smoke pollution from flowering stage in *C.arietinum* and *L.culinaris* while in *P. sativum* the same occurred from preflowering stage.

Potassium

The potassium level decreased in all the three crops at different stages of growth under coal smoke pollution.

The statistical analysis of the data has revealed that the different parameters in a species differ in degree of sensitivity. Depanding on the age of the plant.

According to the degree of response of different parameters, the selected species are listed below in the decreasing order of sensitivity.

1. **Shoot length**

   C. arietinum = *L. culinaris* > *P. sativum*

2. **Root length**

   L. culinaris = *P. sativum* = *C. arietinum*

3. **Branch number per plant**

   P. sativum > *C. arietinum* > *L. culinaris*

4. **Leaf number per plant**

   P. sativum > *C. arietinum* > *L. culinaris*

5. **Leaflet number per leaf**

   P. sativum > *L.culinaris* > *C. arietinum*

6. **Area per leaflet**

   P. sativum > *C. arietinum* > *L. culinaris*

7. **Area per leaf**

   L. culinaris > *C. arietinum* > *P. sativum*

8. **Total green area per plant**

   P. sativum > *C. arietinum* > *L. culinaris*

9. **Shoot biomass**

   L. culinaris > *P. sativum* > *C. arietinum*

10. **Root biomass**

    L. culinaris > *C. arietinum* > *P. sativum*

11. **Phytomass**

    P. sativum *C. arietinum* > *L. culinaris*

12. **Net primary productivity**

    P. sativum > *C. arietinum* > *L. culinaris*

13. **Flower number per** plant

    L. culinaris > *C. arietinum* > *P. sativum*

14. **Fruit number per plant**

    C. arietinum > *P. sativum* > *L. culinaris*

15. **Seed number per pod**

    P. sativum > *C. arietinum* > *L. culinaris*

16. **Seed number per plant**

    C. arietinum > *P. sativum* > *L. culinaris*

17. **Seed weight**

    L.culinaris > *P. sativum* > *C. arietinum*

18. **Harvest index**

    P. sativum > *C. arietinum* > *L. culinaris*

19. **Seed viability**

    P. sativum > *C. arietinum* = *L. culinaris*

20. **Seed germination**

P. sativum > C. arietinum > L. culinaris

21. **Reproductive capacity**

P. sativum > C. arietinum > L. culinaris

22. **Chlorophyll 'a'**

C. arietinum > P. sativum > L. culinaris

Chlorophyll 'b'

P. sativum > C. arietinum > L. culinaris

Total chlorophyll

C. arietinum > P. sativum > L. culinaris

Carotenoids

P. sativum > C. arietinum = L. culinaris

23. **Protein content in root**

C. arietinum > P. sativum > L. culinaris

Protein content in shoot

L.culinaris > P. sativum > C. arietinum

Average protein content of root and shoot

P. sativum > C. arietinum > L. culinaris

24. **Sulphate-sulphur content in root**

P. sativum > C. arietinum > L. culinaris

Sulphate-sulphur content in shoot

P. sativum > C. arietinum > L. culinaris

Average sulphate-sulphur content of root and shoot

P. sativum > C. arietinum > L. culinaris

25. **Nitrogen content**

P. sativum = C. arietinum > L. culinaris

26. Phosphorus content

C. arietinum > *P. sativum* > *L. culinaris*

27. Potassium content

C. arietinum > *L. culinaris* > *P. sativum*

The maximum sensitivity of different parameters occurring at different stages of development in different crops is shown as under:

Growth Stage	*C. arietinum*	*L.culinaris*	*P. sativum*
I	Leaflet area.		leaf area, leaflet area
II.	N.P.P.	Leaflet number, leaf area, total green area	Root length, total green area, Rootbiomass
III.	Leaflet number, leaf area, root biomass, shoot biomass, phytomass.	Branch number leaf number, root biomass, shoot biomass, phytomass, N.P.P.	Phytomass
IV	Root length	Shoot length	Branch number, N.P.P.
V	Leaf number, shoot length, total green area, shoot biomass.	Leaflet area	Shoot length, leaflet number, leaf number, shoot biomass

CONCLUSION

From the present investigation it has been concluded that:-

1. The pulse crops are highly sensitive to coal-smoke pollution.
2. Pulse crops are not to be cultivated in the vicinity of coal based power plants, as the quantum as well as the quality of the yield is highly affected by coal smoke pollution.

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